AN13228

KW45B41Z-EVK RF System Evaluation Report for Bluetooth Low Energy Applications

Rev. 1 — 28 April 2023 Application note

Document Information

Information	Content
Keywords	AN13228, KW45B41Z-EVK, low-power, Bluetooth LE
Abstract	This document provides the RF evaluation test results of the KW45B41Z-EVK for Bluetooth Low Energy (LE) applications on Two Frequency Shift Keying (2FSK) modulation

1 Introduction

This document provides the RF evaluation test results of the KW45B41Z-EVK for Bluetooth Low Energy (LE) applications on Two Frequency Shift Keying (2FSK) modulation. It includes the test setup description and the tools used to perform the tests on your own. To get the KW45 radio parameters, see the *KW45B41Z Data Sheet* (document KW45B41Z).

For more information about the KW45B41Z-EVK Evaluation Kit Board, see the *KW45B41Z-EVK Board User Manual* (document KW45B41Z-EVKUM).

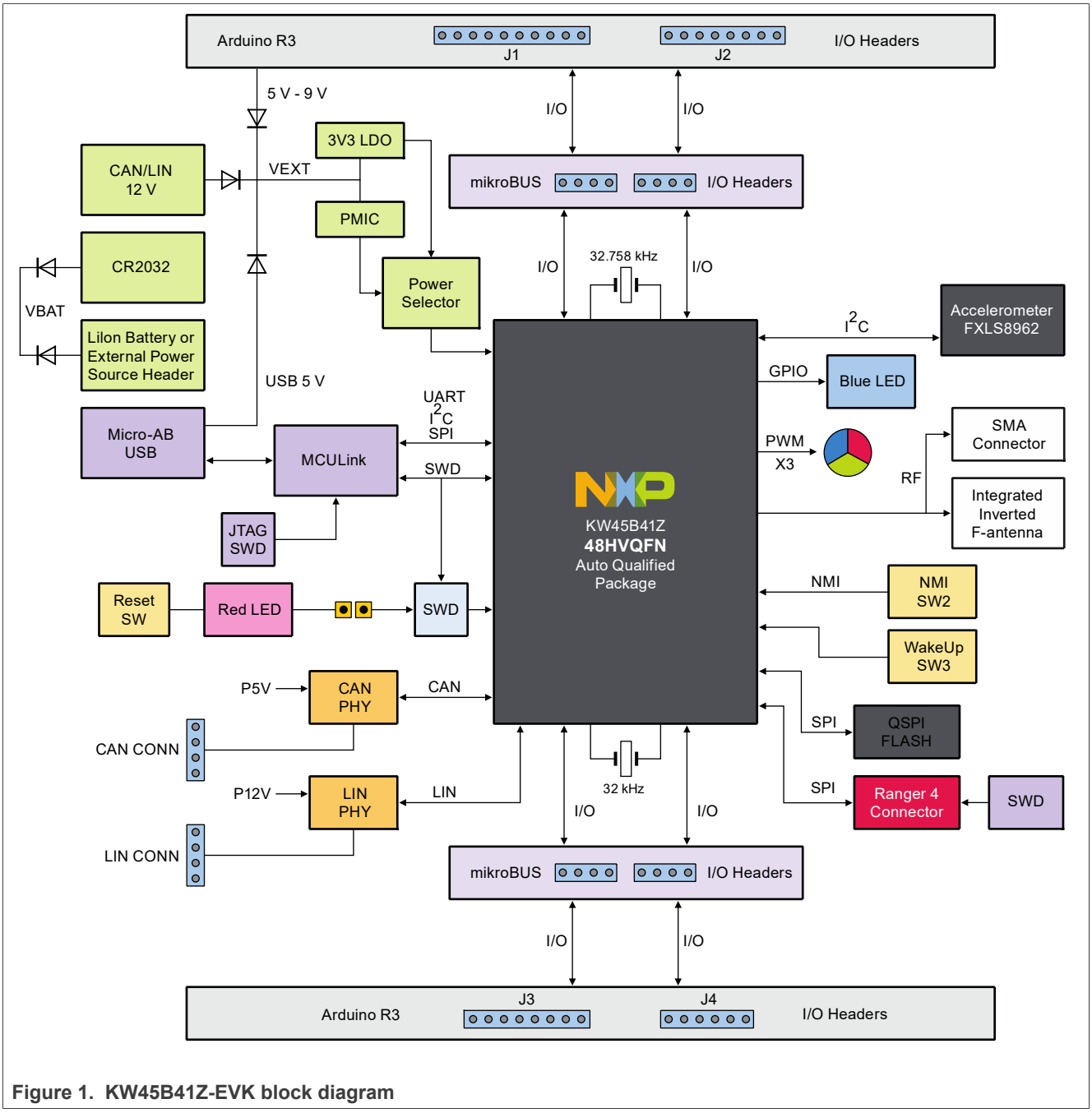


Figure 1. KW45B41Z-EVK block diagram

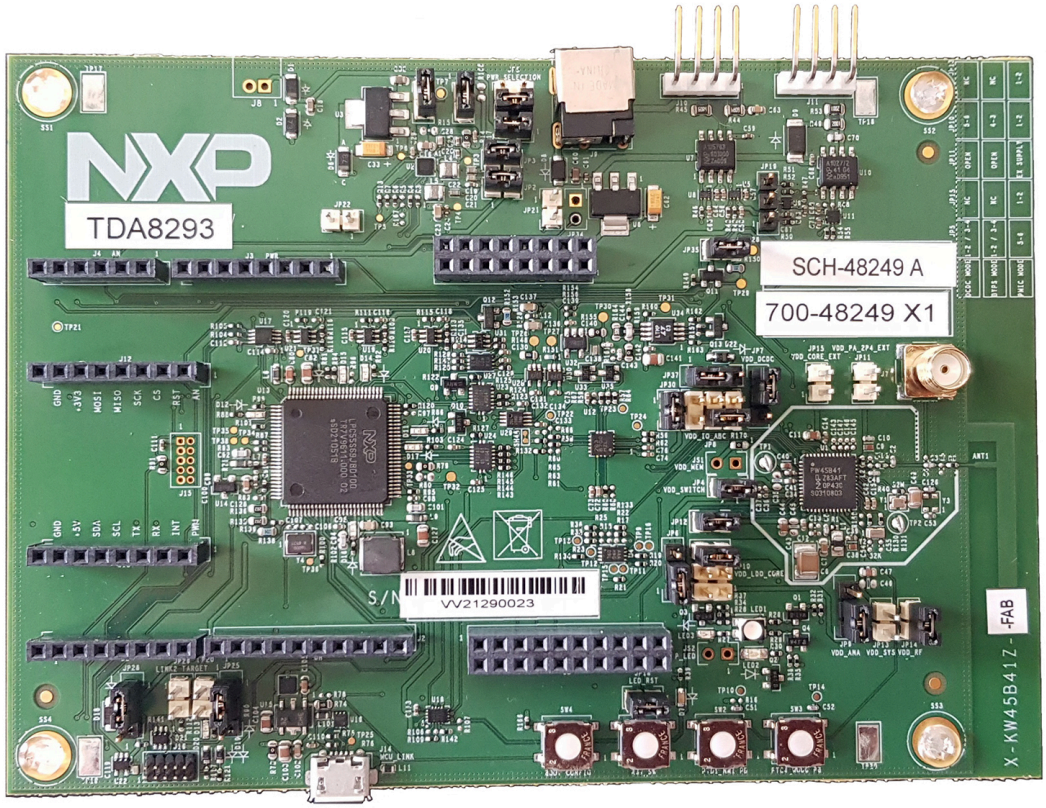


Figure 2. KW45B41Z-EVK top-side view

1.1 List of tests

Conducted tests on KW45B41Z-EVK:

- TX tests:
  - Bench setup
  - Frequency accuracy
  - Phase noise
  - TX power Bluetooth LE 1 Msps, 2 Msps, 500 ksps (LR S=2), 125 ksps (LR S=8)
  - TX power in band
  - TX spurious (H2 to H10, ETSI, and FCC)
  - Lower band edge (MIIT-China)
  - Upper band edge
  - Maximum TX output power 1 Msps, 2 Msps, 500 ksps (LR S=2), 125 ksps (LR S=8)
  - Bluetooth LE TX output spectrum 1 Msps, 2 Msps
  - Modulation characteristics 1 Msps, 2 Msps, 125 ksps LR (S=8)
  - Carrier frequency offset and drift 1 Msps, 2 Msps, 125 ksps LR (S=8)
- RX tests:
  - Bench setup
  - Sensitivity 1 Msps, 2 Msps, LR (S=2 and S=8)
  - Bathtub 1 Msps, 2 Msps, LR (S=2 and S=8)
  - Receiver maximum input level 1 Msps, 2 Msps, LR (S=2 and S=8)

  - RX spurious (from 30 MHz to 12.5 GHz)
  - Receiver interference rejection performances
    - Adjacent, Alternate, and co-channel rejection – 1 Msps, 2 Msps, 500 ksps (LR S=2), 125 ksps (LR S=8)
    - Receiver blocking – 1 Msps – cat.1 and cat.2
    - Blocking interferers
  - Intermodulation
- Return loss (S11):
  - RX
  - TX

1.2 Software

Before measuring, a binary code (connectivity software) must be loaded into the flash memory of the board. For how to use KW45B41Z-EVK to load the code, see *Getting Started KW45*.

The binary code used for the following tests is the connectivity software package GenFSK protocol (2FSK modulation) and the HCI_blackbox. The Tera Term terminal emulator is used to communicate with the KW45 MCU.

The list of equipment used to perform the RX and TX measurements are as follows:

1. Spectrum analyzer - 25 GHz for harmonic measurements up to H10
2. R&S SFU - It can be any generator with ARB which is used as an interferer source for 802.15.4
3. MXG (Agilent N5182A)
4. R&S CMW270 (HCI_blackbox software)
5. Agilent SML03
6. Agilent 33250A
7. R&S ZND vector network analyzer for S11 measurements
8. RF shielded box to avoid interferers and RF horn for radiated measurements
9. Power supply
10. PC equipped with a GPIB card

Note: *The KW45B41Z-EVK VV21290023 is used to perform all RF test measurements.*

2 Tests summary

RF PHY Bluetooth test specification: RF-PHY.TS.5.0.2 (2017-12-07)

The list of measurements is given in Table 1 for Europe and Table 2 for the US.

Table 1. List of tests for Europe

Name	Measurements	Reference	Limit	Status
Transmission	TX maximum output power	Bluetooth LE 5.0, BV-01-C	-20 dBm ≤ PAVG ≤ +10 dBm EIRP	PASS
	TX power in band 1 Msps	Bluetooth LE 5.0, BV-03-C	PTX <= -20 dBm for (fTX +/- 2 MHz)	PASS
			PTX <= -30 dBm for (fTX +/- [3 + n] MHz]);	
	TX power in band 2 Msps	Bluetooth LE 5.0, BV-08-C	PTX <= -20 dBm for (fTX +/- 4 MHz) and (fTX +/- 5 MHz)	PASS
			PTX <= -30 dBm for (fTX +/- [3 + n] MHz]);	
	Modulation characteristics 1 Msps LE coded (S=8)	Bluetooth LE 5.0, BV-05-C Bluetooth LE 5.0, BV-13-C	225 kHz <= delta f1avg <= 275 kHz	PASS
	Modulation characteristics 2 Msps	Bluetooth LE 5.0, BV-10-C	450 kHz <= delta f1avg <= 550 kHz	PASS

Table 1. List of tests for Europe*...continued*

Name	Measurements	Reference	Limit	Status
	Carrier frequency offset and drift1 Msps	Bluetooth LE 5.0, BV-06-C	fTX – 150 kHz <= fn <= fTX + 150 kHz where fTX is the nominal transmit frequency and n=0,1,2,3…k |f0 – fn| <= 50 kHz where n=2,3,4…k	PASS
	Carrier frequency offset and drift 2 Msps	Bluetooth LE 5.0, BV-12-C	|f0 – f3| <= 19.2 kHz |f0 – f(n-3)| <= 19.2 kHz where n=7,8,9,…k	
	Carrier frequency offset and drift LE coded (S=8)	Bluetooth LE 5.0, BV-14-C	fTX – 150 kHz <= fn <= fTX + 150 kHz where fTX is the nominal transmit frequency and n=0,1,2,3…k |f0 – fn| <= 50 kHz where n=2,3,4…k	PASS
	Spurious 30 MHz - 1 GHz	ETSI EN 300 328 v2.2.1 (2019-04)	-36 dBm or -54 dBm (depends on frequency) (100 kHz BW)	PASS
	Spurious 1 GHz - 25 GHz	ETSI EN 300 328 v2.2.1 (2019-04)	-30 dBm (1 MHz BW)	PASS
	Eirp TX spectral density	ETSI EN 300 328 v2.2.1 (2019-04)	10 dBm / MHz	PASS
	Phase noise (unspread)	NA	NA	For information
	RX Sensitivity - 1 Msps	Bluetooth LE 5.0, BV-01-C	Packet Error Rate (PER) 30.8 % with a minimum of 1500 packets	PASS
Reception	RX Sensitivity - 2 Msps	Bluetooth LE 5.0, BV-08-C	PER 30.8 % with a minimum of 1500 packets	PASS
	RX Sensitivity - LE coded (S=2)	Bluetooth LE 5.0, BV-26-C	PER 30.8 % with a minimum of 1500 packets	PASS
	RX Sensitivity - LE coded (S=8)	Bluetooth LE 5.0, BV-27-C	PER 30.8 % with a minimum of 1500 packets	PASS
	Co-channel - 1 Msps	Bluetooth LE 5.0, BV-03-C	> 21 dB	PASS
	Adjacent channel interference rejection (N+/-1,2,3+MHz) 1 Msps	Bluetooth LE 5.0, BV-03-C	> 15 dB, - 17 dB, - 27 dB	PASS
	Co-channel - 2 Msps	Bluetooth LE 5.0, BV-09-C	> 21 dB	PASS
	Adjacent channel interference rejection (N+/-2,4,6+MHz) - 2 Msps	Bluetooth LE 5.0, BV-09-C	> 15 dB, - 17 dB, - 27 dB	PASS
	Co-channel - LE coded (S=2)	Bluetooth LE 5.0, BV-28-C	> 17 dB	PASS
	Adjacent channel interference rejection (N+/-2,4,6+MHz) LE coded (S=2)	Bluetooth LE 5.0, BV-09-C	> 11 dB, - 21 dB, - 31 dB	PASS
	Co-channel - LE coded (S=8)	Bluetooth LE 5.0, BV-28-C	> 12 dB	PASS
	Adjacent channel interference rejection (N+/-2,4,6+MHz) LE coded (S=8)	Bluetooth LE 5.0, BV-09-C	> 6 dB, - 26 dB, - 36 dB	PASS
	Blocking interferers 1 Msps 2 Msps	Bluetooth LE 5.0, BV-04-C Bluetooth LE 5.0, BV-010-C	-30 dBm (30 MHz -2 GHz and 3 GHz - 12.5 GHz) - 35 dBm (2003 MHz - 2399 MHz and 2484 MHz - 2997 MHz)	PASS
	Intermodulation 1 Msps, 2 Msps	Bluetooth LE 5.0, BV-05-C Bluetooth LE 5.0, BV-11-C	PER 30.8 % with a minimum of 1500 packets	PASS
	RX maximum input level 1 Msps, 2 Msps	Bluetooth LE 5.0, BV-06-C Bluetooth LE 5.0, BV-12-C	PER 30.8 % with a minimum of 1500 packets	PASS
	RX emissions 30 MHz - 1 GHz	ETSI EN 300 328 v2.2.1 (2019-04)	-57 dBm (100 kHz)	PASS
	RX emissions 1 GHz - 12.5 GHz	ETSI EN 300 328 v2.2.1 (2019-04)	-47 dBm (1 MHz)	PASS
Miscellaneous	Return loss (S11)	Return loss in TX mode	-	For information
		Return loss in RX mode	-	For information

Table 2. List of tests for the US

Name	Measurements	Reference	Limit	Status
Transmission	TX maximum power	FCC part15.247	PAVG ≤ 100 mW +20 dBm EIRP	PASS

Table 2. List of tests for the US...*continued*

Name	Measurements	Reference	Limit	Status
	Spurious 1 GHz - 25 GHz	FCC part15.249	Field strength < 50 mV/m @3m -41.12 dBm (1 MHz BW)	PASS

3 Conducted tests

This section lists the details about TX tests, RX tests, and return losses.

3.1 TX tests

This section lists the details about TX tests.

3.1.1 Test setup

Figure 3 and Figure 4 show the test setup.

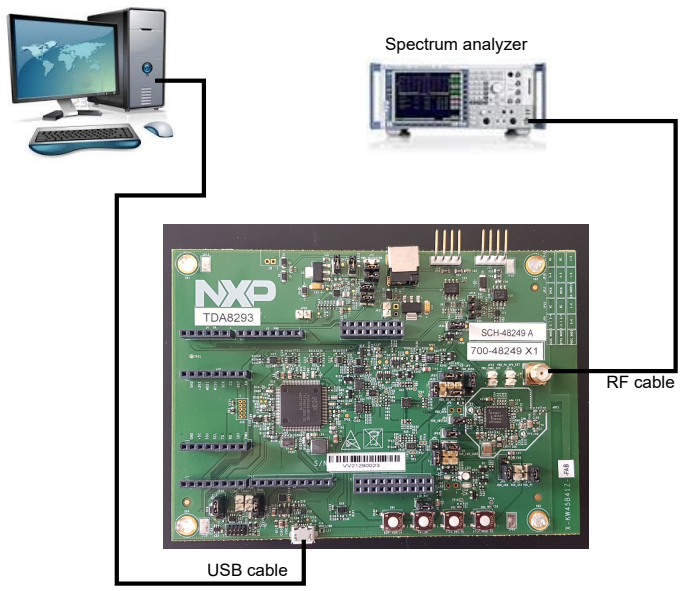


Figure 3. Conducted TX test setup

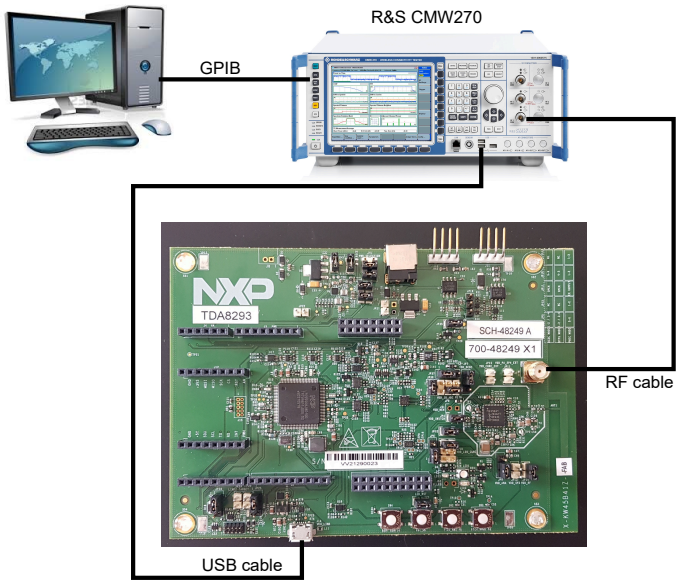


Figure 4. Specific conducted TX test setup

3.1.2 Frequency accuracy

Test method:

1. Set the radio to:
   - TX mode
   - CW
   - Continuous mode
   - Frequency: Channel 19
2. Set the analyzer to:
   - Center frequency = 2.44 GHz
   - Span = 1 MHz
   - Ref amp = 20 dBm
   - RBW = 10 kHz
   - VBW = 100 kHz
3. Measure the CW frequency with the marker of the spectrum analyzer

Result:

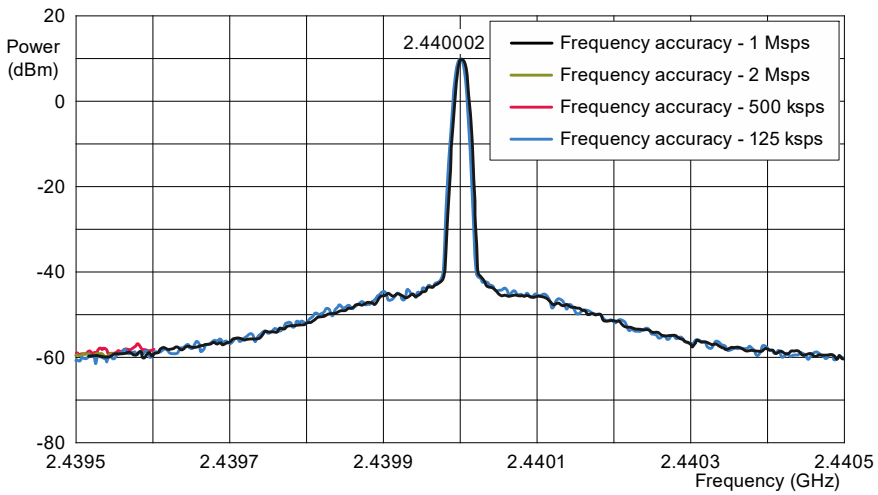


Figure 5. Frequency accuracy

- Measured frequency: 2.44002 GHz
- ppm value = (2.440020-2.440000) / 2.440 = +0.8 ppm

Table 3. Frequency accuracy

Result	Target
+0.8 ppm	+/-25 ppm

Note: *The frequency accuracy depends on the XTAL model. The model used on KW45B41Z-EVK is NX2016SA EXS00A-CS14160 (NDK).*

Conclusion:

- The frequency accuracy complies with the data sheet

3.1.3 Phase noise

Test method:

1. Set the radio to:
   - TX mode
   - CW
   - Continuous mode
   - Frequency: Channel 19
2. Set the analyzer to:
   - Center frequency = 2.44 GHz
   - Span = 1 MHz
   - Ref amp = 20 dBm
   - RBW = 10 kHz
   - VBW = 100 kHz
3. Measure the phase noise at the 100 kHz offset frequency:
   - RBW (spectrum analyzer) = 10 kHz (20 log at 10 kHz = 40 dBc)

Result:

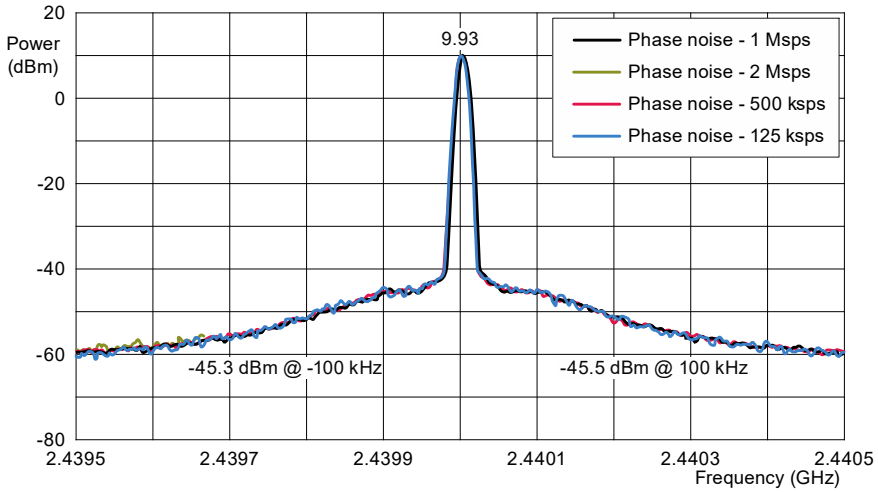


Figure 6. Conducted phase noise

- Marker value (delta) = -45.3 dBm / 100 kHz = -95.3 dBc/Hz

Note: *The phase noise is just for informational purposes. No specific issue on this parameter.*

3.1.4 TX power (fundamental)

Test method:

1. Set the radio to:
   - TX mode
   - Modulated
   - Continuous mode
   - Data rate: 1 Msps, 2 Msps, 500 ksps, 125 ksps
2. Set the analyzer to:
   - Start frequency = 2.4 GHz
   - Stop frequency = 2.5 GHz
   - Ref amp = 10 dBm
   - Sweep time = 100 ms
   - RBW = 3 MHz
   - VBW = 3 MHz
   - Max Hold mode
   - Detector = RMS
3. Sweep all the channels from channel 0 to channel 39:
   - Software tool allows sweep from 2.36 GHz to 4.88 GHz

Result:

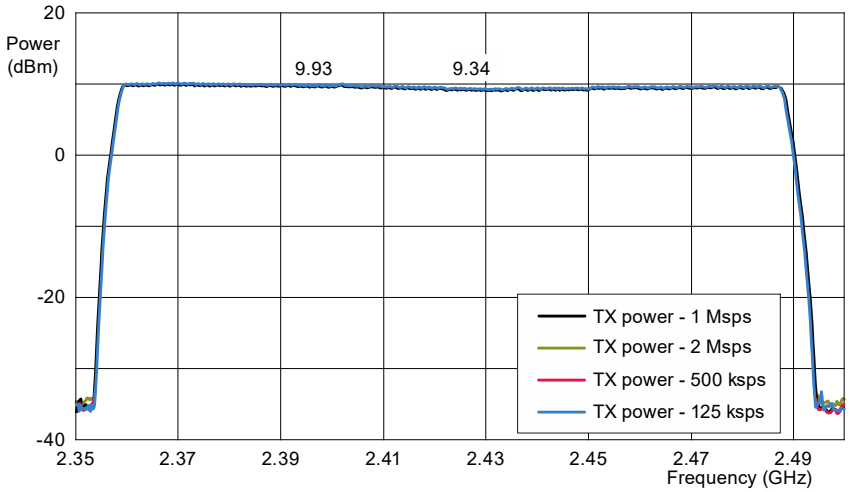


Figure 7. TX power

- Maximum power is on channel 0: 9.93 dBm
- Minimum power is on channel 15: 9.34 dBm
- Tilt over frequencies is 0.6 dB

Conclusion:

- The default TX power is in line with the expected results
- The power is flat over frequencies

3.1.5 TX power in band

Test method:

1. Set the radio to:
   - TX mode
   - Modulated
   - Continuous mode
   - Data rate: 1 Msps, 2 Msps, 500 ksps, 125 ksps
2. Set the analyzer to:
   - Start frequency = 2.35 GHz
   - Stop frequency = 2.5 GHz
   - Ref amp = 10 dBm
   - Sweep time = 100 ms
   - RBW = 100 kHz
   - VBW = 300 kHz
   - Max Hold mode
   - Detector = RMS
   - Number of Sweeps = 10
3. Sweep on channel 2, channel 19, and channel 37

Result:

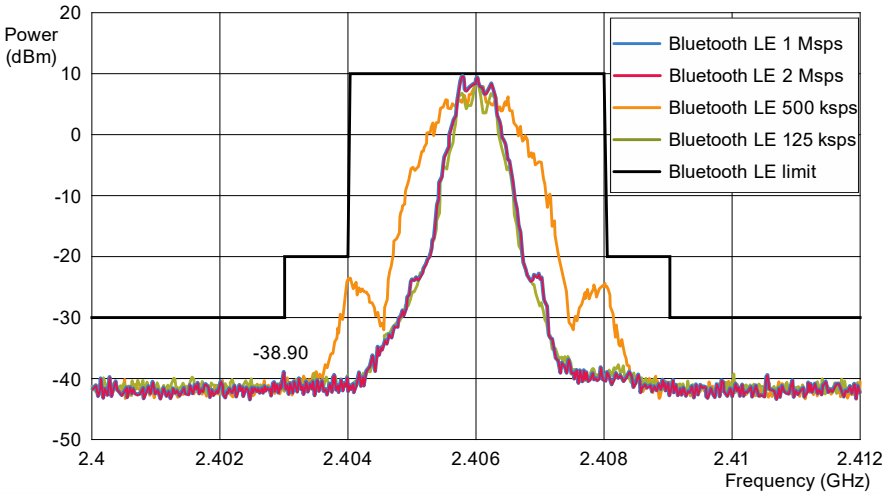


Figure 8. TX power in band, channel 2

Table 4. Bluetooth LE 1 Msps

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-2 MHz	-39.43	2.404
Max peak level >=+2 MHz	-38.84	2.408
Max peak level <=-3 MHz	-38.90	2.403
Max peak level >=+3 MHz	-39.62	2.411

Table 5. Bluetooth LE 2 Msps

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-2 MHz	-23.71	2.404
Max peak level >=+2 MHz	-24.88	2.408
Max peak level <=-3 MHz	-40.06	2.400
Max peak level >=+3 MHz	-40.27	2.412

Table 6. Bluetooth LE 500 ksps

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-2 MHz	-39.43	2.404
Max peak level >=+2 MHz	-38.84	2.408
Max peak level <=-3 MHz	-38.90	2.403
Max peak level >=+3 MHz	-39.62	2.411

Table 7. Bluetooth LE 125 ksps

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-2 MHz	-39.10	2.403
Max peak level >=+2 MHz	-37.76	2.408

Table 7. Bluetooth LE 125 ksps*...continued*

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-3 MHz	-39.93	2.402
Max peak level >=+3 MHz	-39.35	2.410

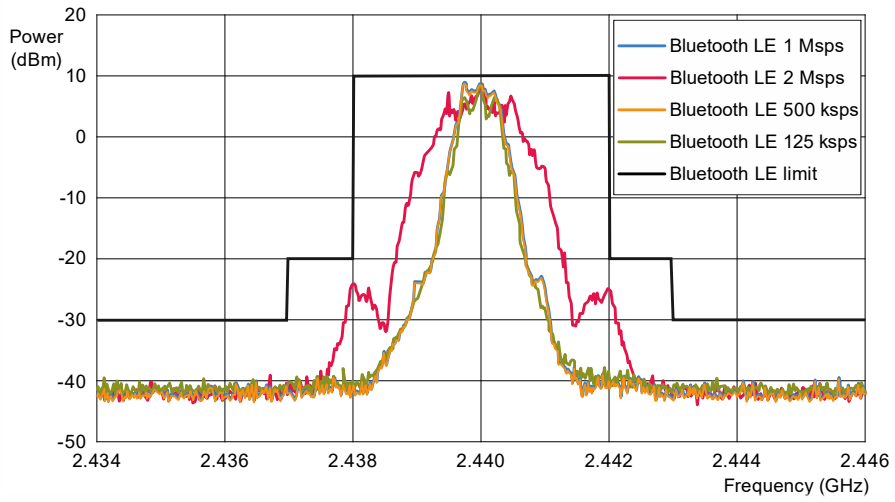


Figure 9. TX power in band, channel 19

Table 8. Bluetooth LE 1 Msps

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-2 MHz	-39.43	2.437
Max peak level >=+2 MHz	-39.37	2.442
Max peak level <=-3 MHz	-40.22	2.436
Max peak level >=+3 MHz	-39.49	2.446

Table 9. Bluetooth LE Msps

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-2 MHz	-24.58	2.438
Max peak level >=+2 MHz	-25.11	2.442
Max peak level <=-3 MHz	-39.18	2.437
Max peak level >=+3 MHz	-40.54	2.445

Table 10. Bluetooth LE 500 ksps

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-2 MHz	-39.43	2.437
Max peak level >=+2 MHz	-39.37	2.442
Max peak level <=-3 MHz	-40.22	2.436

Table 10. Bluetooth LE 500 ksps*...continued*

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level >=+3 MHz	-39.49	2.446

Table 11. Bluetooth LE 125 ksps

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-2 MHz	-38.04	2.438
Max peak level >=+2 MHz	-38.39	2.442
Max peak level <=-3 MHz	-39.60	2.434
Max peak level >=+3 MHz	-39.63	2.444

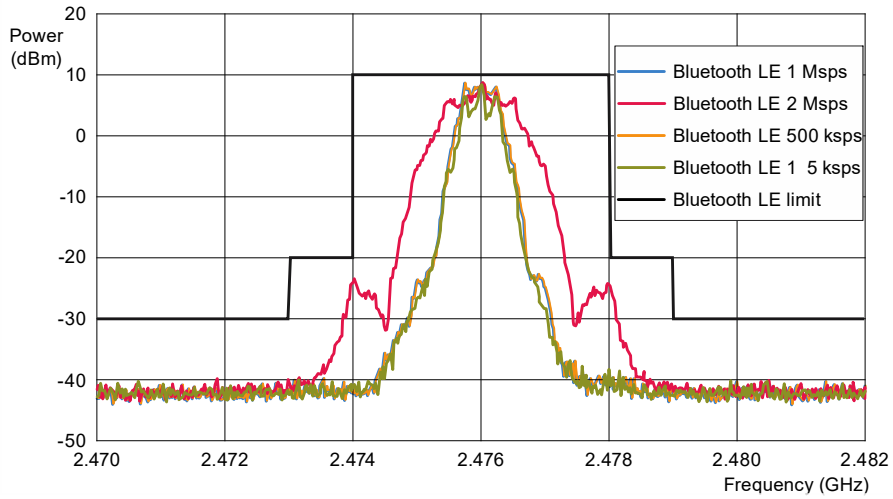


Figure 10. TX power in band, channel 37

Table 12. Bluetooth LE 1 Msps

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-2 MHz	-39.93	2.474
Max peak level >=+2 MHz	-39.75	2.478
Max peak level <=-3 MHz	-40.56	2.473
Max peak level >=+3 MHz	-40.35	2.481

Table 13. Bluetooth LE 2 Msps

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-2 MHz	-24.10	2.474
Max peak level >=+2 MHz	-24.69	2.478
Max peak level <=-3 MHz	-39.96	2.473
Max peak level >=+3 MHz	-40.21	2.480

Table 14. Bluetooth LE 500 ksps

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-2 MHz	-39.93	2.474
Max peak level >=+2 MHz	-39.75	2.478
Max peak level <=-3 MHz	-40.56	2.473
Max peak level >=+3 MHz	-40.35	2.481

Table 15. Bluetooth LE 125 ksps

Bandwidth	Power (dBm)	Frequency (GHz)
Max peak level <=-2 MHz	-40.15	2.473
Max peak level >=+2 MHz	-38.53	2.478
Max peak level <=-3 MHz	-40.24	2.471
Max peak level >=+3 MHz	-40.15	2.480

Conclusion:

- These results are compliant to Bluetooth LE 5.0

3.1.6 TX spurious

3.1.6.1 30 MHz to 25 GHz

Spurious overview of the full band from 30 MHz to 25 GHz when the device is in the transmission mode.

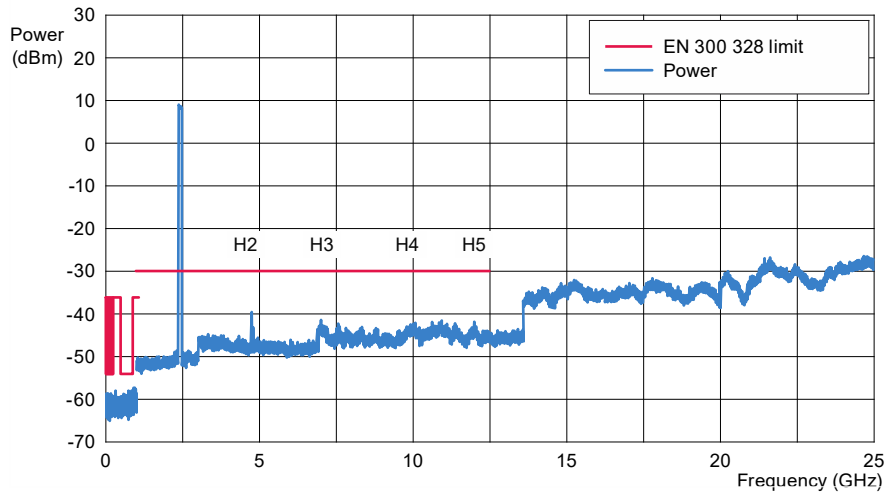


Figure 11. Conducted TX spurious (30 MHz to 25 GHz)

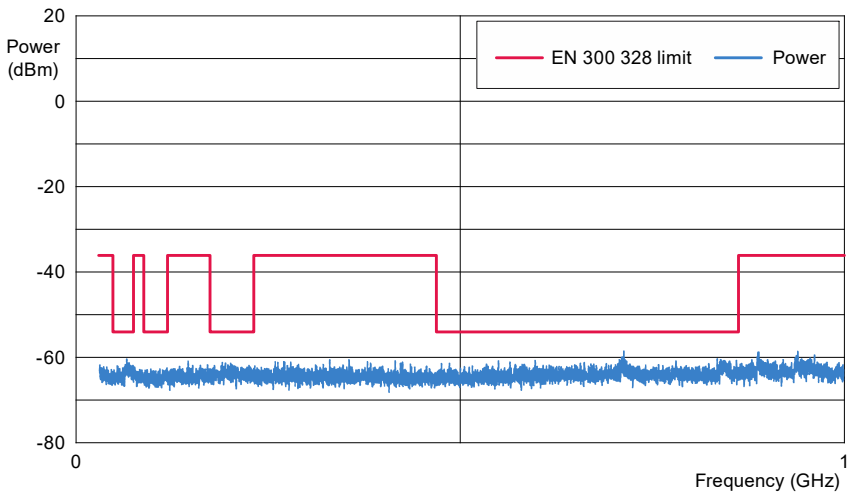


Figure 12. Zoom In - conducted TX spurious (30 MHz to 1 GHz)

Conclusion:

- There are no TX spurs above the EN 300 328 limit (more than 4 dB margin)
- Harmonics are measured in the following paragraphs

3.1.6.2 H2 (ETSI test conditions, peak measurement)

Test method:

1. Set the radio to:
   - TX mode
   - Modulated
   - Continuous mode
2. Set the analyzer to:
   - Start frequency = 4.7 GHz
   - Stop frequency = 5 GHz
   - Ref amp = -20 dBm
   - Sweep time = 100 ms
   - RBW = 1 MHz
   - VBW = 3 MHz
   - Max Hold mode
   - Detector: Peak
3. Sweep all the channels from channel 0 to channel 39

Result:

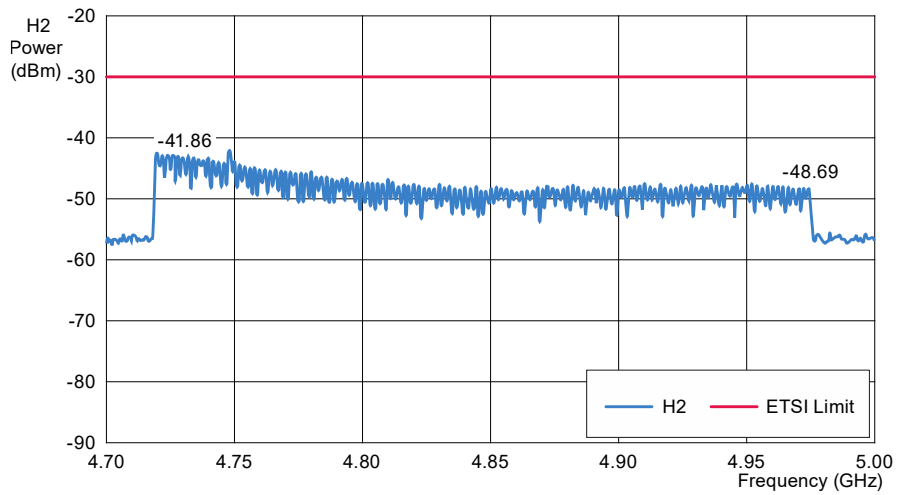


Figure 13. Conducted H2 spurious

- Maximum power at frequency 4.748 GHz is -41.86 dBm

Conclusion:

- There is more than 11 dB margin to the ETSI limit

3.1.6.3 H3 (ETSI test conditions, peak measurement)

The test method is same as for the H2, except that the spectrum analyzer frequency start/stop is set to 7.0 GHz and 7.5 GHz.

Result:

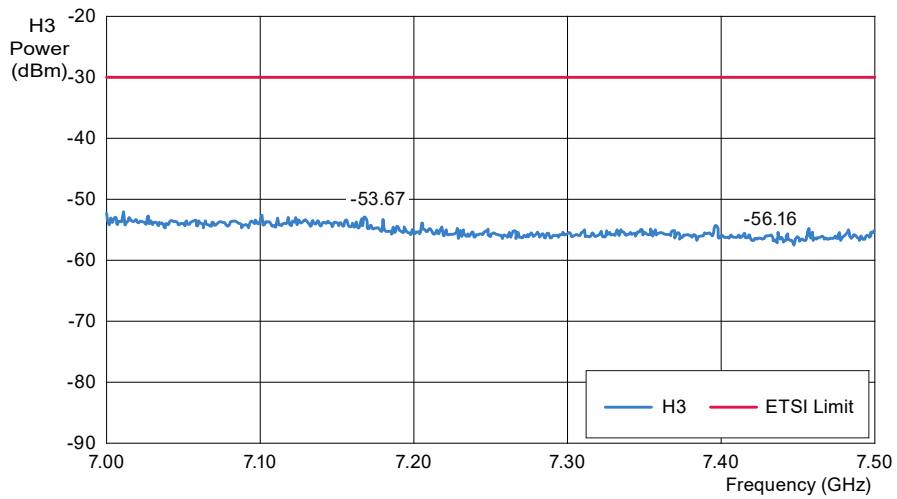


Figure 14. Conducted H3 spurious

- Maximum power at frequency 7.098 GHz is -53.67 dBm

Conclusion:

- There is more than 23 dB margin to the ETSI limit

3.1.6.4 H4 (ETSI test conditions, peak measurement)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 9.4 GHz to 10.0 GHz.

Result:

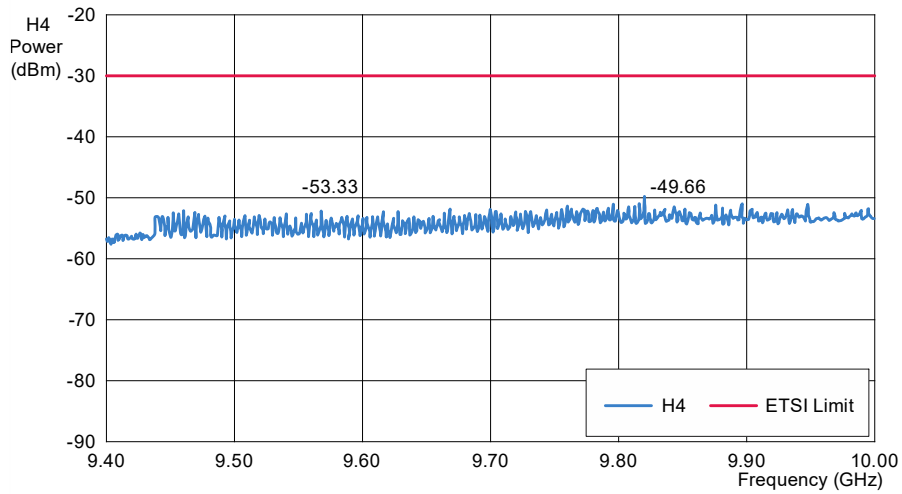


Figure 15. Conducted H4 spurious

- Maximum power at frequency 9.82 GHz is -49.66 dBm

Conclusion:

- There is more than 19 dB margin to the ETSI limit

3.1.6.5 H5 (ETSI test conditions, peak measurement)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 11.7 GHz to 12.5 GHz.

Result:

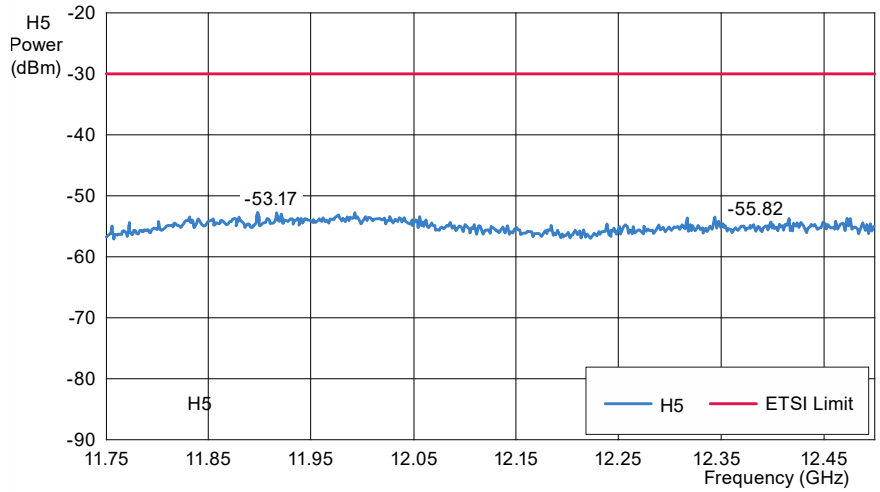


Figure 16. Conducted H5 spurious

- Maximum power at frequency 12.0275 GHz is -53.17 dBm

Conclusion:

- There is more than 23 dB margin to the ETSI limit

3.1.6.6 H6 (ETSI test conditions, peak measurement)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 14.1 GHz to 15 GHz.

Result:

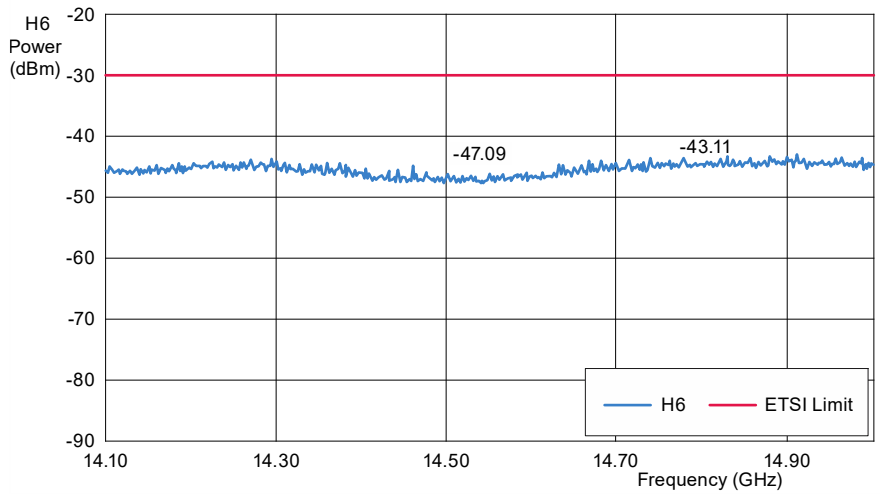


Figure 17. Conducted H6 spurious

- Maximum power at frequency 14.9118 GHz is -43.11 dBm

Conclusion:

- There is more than 13 dB margin to the ETSI limit

3.1.6.7 H7 (ETSI test conditions, peak measurement)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 16.45 GHz to 17.5 GHz.

Result:

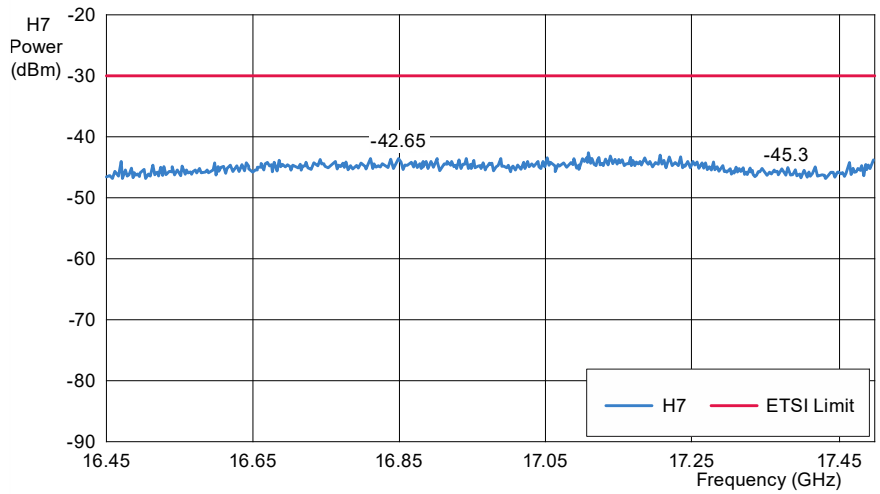


Figure 18. Conducted H7 spurious

- Maximum power at frequency 17.1199 GHz is -42.65 dBm

Conclusion:

- There is more than 12 dB margin to the ETSI limit

3.1.6.8 H8 (ETSI test conditions, peak measurement)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 16.45 GHz to 17.5 GHz.

Result:

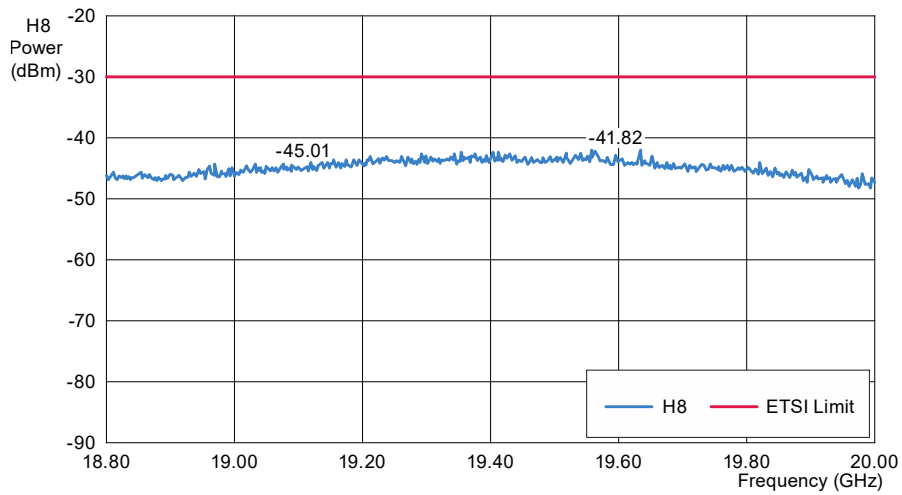


Figure 19. Conducted H8 spurious

- Maximum power at frequency 19.6328 GHz is -41.82 dBm

Conclusion:

- There is more than 11 dB margin to the ETSI limit

3.1.6.9 H9 (ETSI test conditions, peak measurement)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 21.15 GHz to 22.5 GHz.

Result:

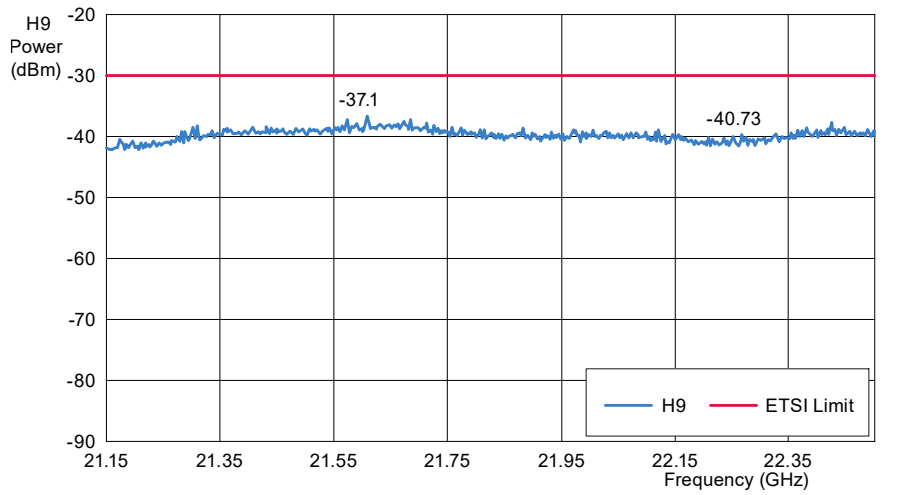


Figure 20. Conducted H9 spurious

- Maximum power at frequency 21.6819 GHz is -37.1 dBm

Conclusion:

- There is more than 7 dB margin to the ETSI limit

3.1.6.10 H10 (ETSI test conditions, peak measurement)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 23.35 GHz to 25 GHz.

Result:

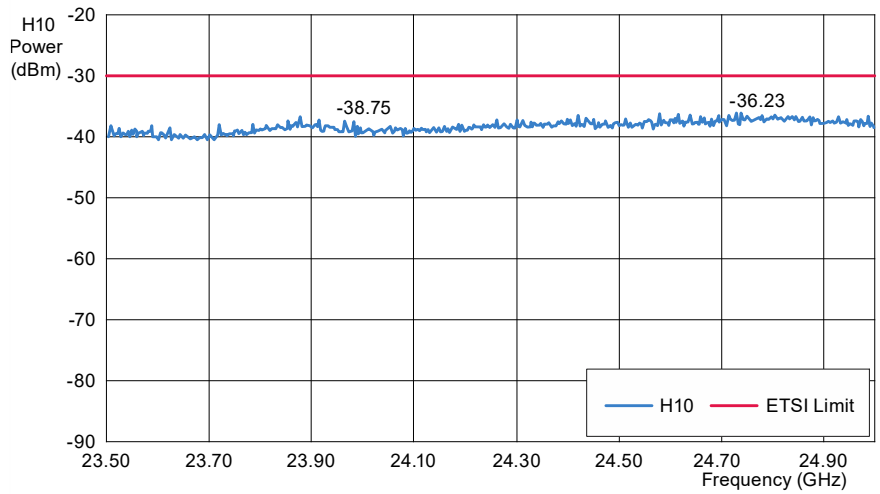


Figure 21. Conducted H10 spurious

- Maximum power at frequency 24.739 GHz is -36.23 dBm

Conclusion:

- There is more than 6 dB margin to the ETSI limit

3.1.6.11 H2 (FCC test conditions, average measurements)

Test method:

1. Set the radio to:
   - TX mode
   - Modulated
   - Continuous mode
2. Set the analyzer to:
   - Start frequency = 4.7 GHz
   - Stop frequency = 5 GHz
   - Ref amp = -20 dBm
   - Sweep time = 100 ms
   - RBW = 1 MHz
   - VBW = 3 MHz
   - Trace: Max Hold mode
   - Detector: RMS
3. Sweep all the channels from channel 0 to channel 39

Result:

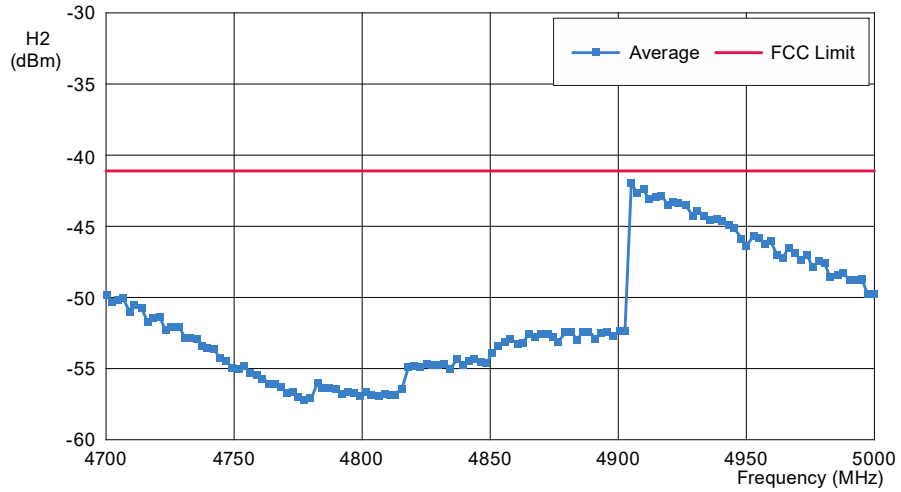


Figure 22. Conducted H2 FCC spurious

- Maximum power at frequency 4.906 GHz is -42.14 dBm

Conclusion:

- There is more than 1 dB margin to the FCC limit

3.1.6.12 H3 (FCC test conditions, average measurements)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 7.0 GHz to 7.5 GHz.

Result:

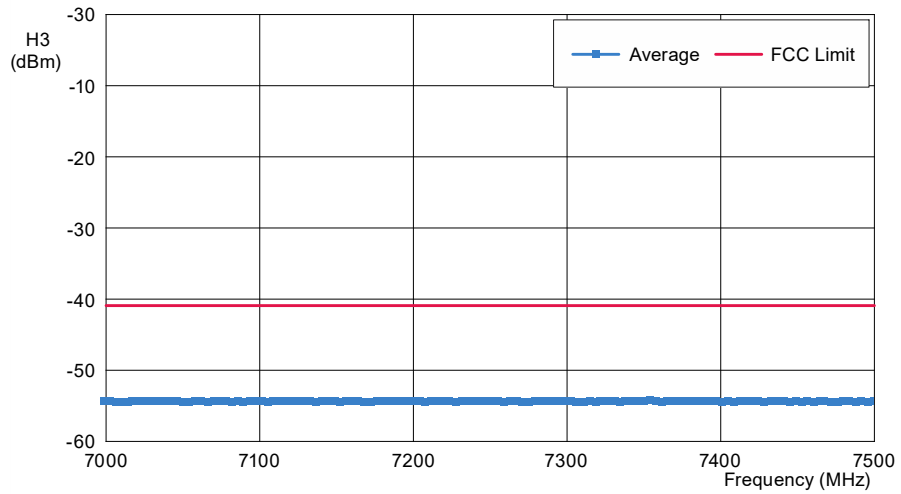


Figure 23. Conducted H3 FCC spurious

- Maximum power at frequency 7.354 GHz is -54.27 dBm

Conclusion:

- There is more than 13 dB margin to the FCC limit

3.1.6.13 H4 (FCC test conditions, average measurements)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 9.4 GHz to 10 GHz.

Result:

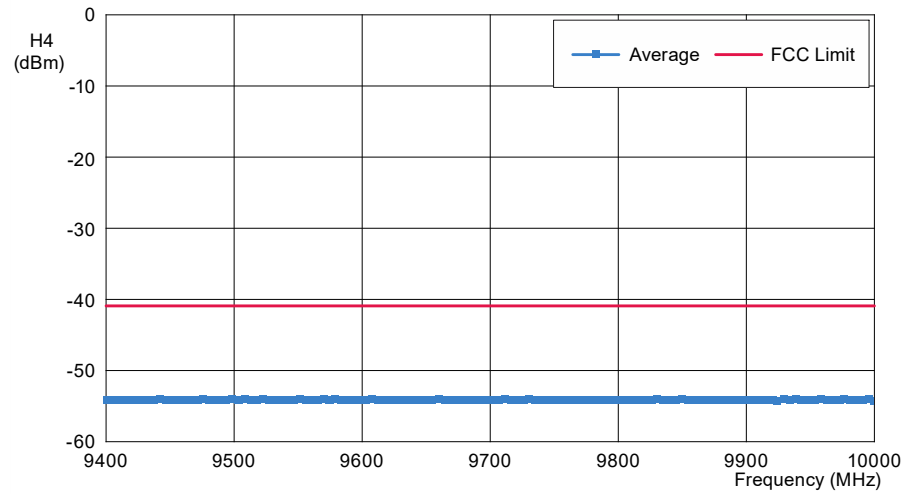


Figure 24. Conducted H4 FCC spurious

- Maximum power at frequency 9.939 GHz is -54.09 dBm

Conclusion:

- There is more than 13 dB margin to the FCC limit

3.1.6.14 H5 (FCC test conditions, average measurements)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 11.7 GHz to 12.5 GHz.

Result:

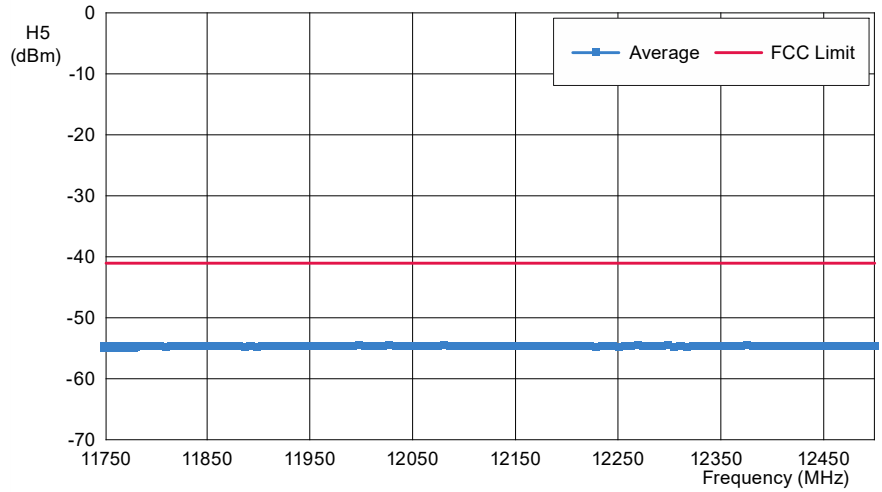


Figure 25. Conducted H5 FCC spurious

- Maximum power at frequency 12.081 GHz is -54.59 dBm

Conclusion:

- There is more than 13 dB margin to the FCC limit

3.1.6.15 H6 (FCC test conditions, average measurements)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 14.1 GHz to 15 GHz.

Result:

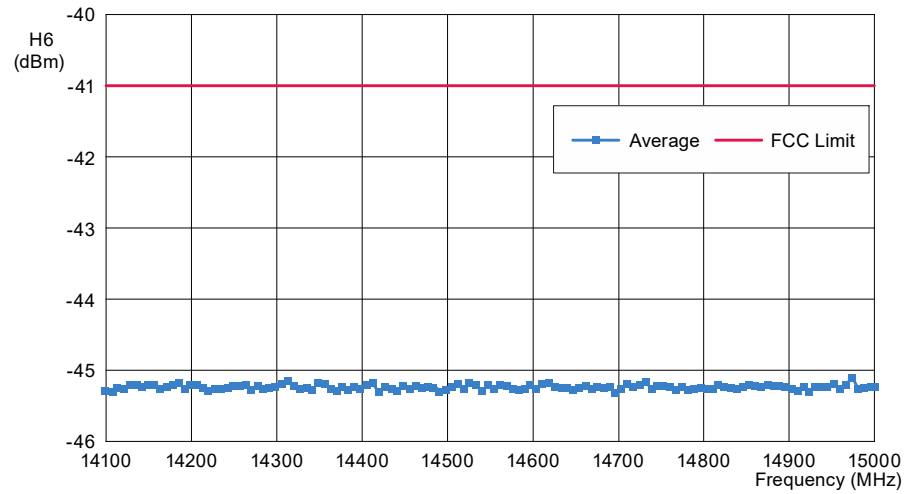


Figure 26. Conducted H6 FCC spurious

- Maximum power at frequency 14.972 GHz is -45.11 dBm

Conclusion:

- There is more than 4 dB margin to the FCC limit

3.1.6.16 H7 (FCC test conditions, average measurements)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 16.45 GHz to 17.5 GHz.

Result:

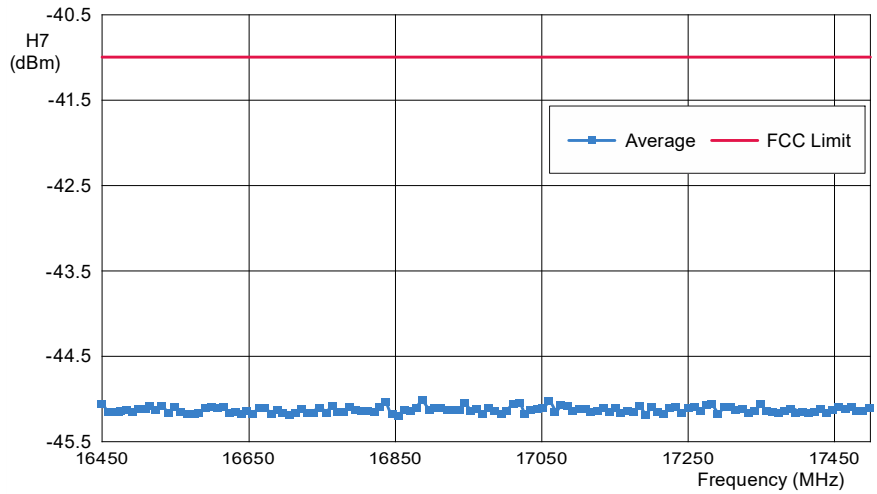


Figure 27. Conducted H7 FCC spurious

- Maximum power at frequency 16.888 GHz is -45.02 dBm

Conclusion:

- There is more than 4 dB margin to the FCC limit

3.1.6.17 H8 (FCC test conditions, average measurements)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 16.45 GHz to 17.5 GHz.

Result:

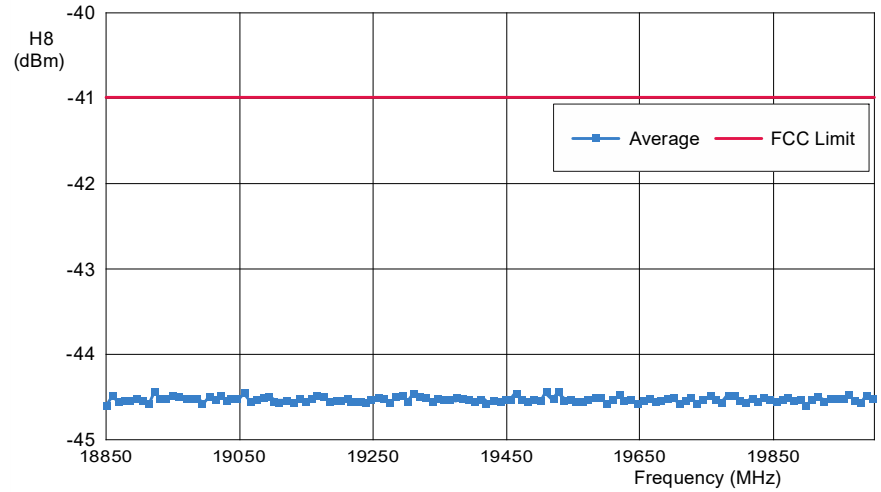


Figure 28. Conducted H8 FCC spurious

- Maximum power at frequency 19.511 GHz is -44.44 dBm

Conclusion:

- There is more than 3 dB margin to the FCC limit

3.1.6.18 H9 (FCC test conditions, average measurements)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 21.15 GHz to 22.5 GHz.

Result:

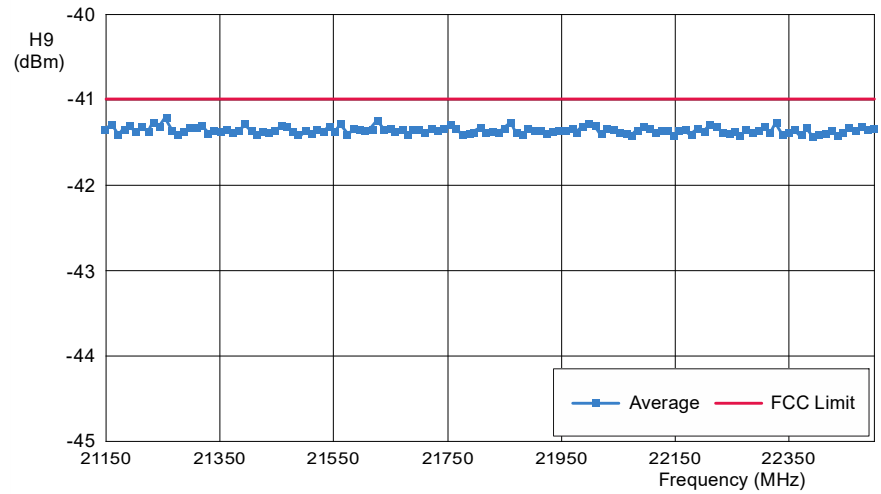


Figure 29. Conducted H9 FCC spurious

- Maximum power at frequency 21.256 GHz is -41.22 dBm

Conclusion:

- There is no margin (~0.2 dB) to the FCC limit

3.1.6.19 H10 (FCC test conditions, average measurements)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 23.35 GHz to 25 GHz.

Result:

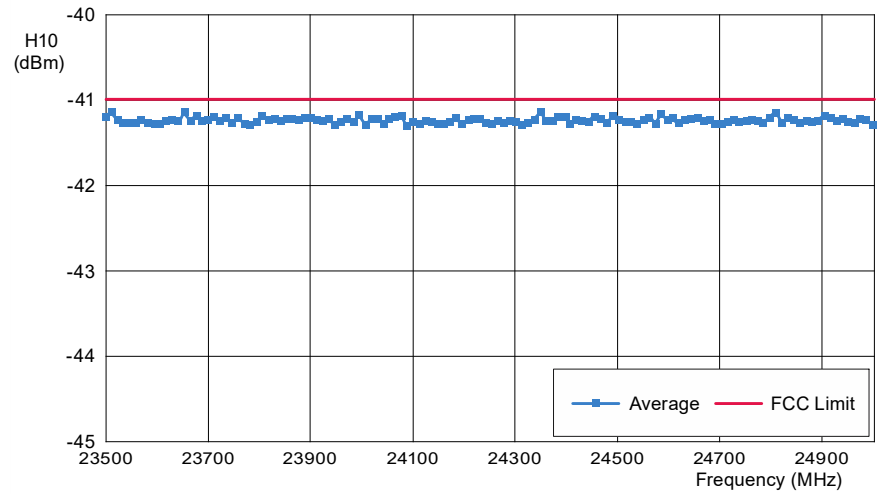


Figure 30. Conducted H10 FCC spurious

- Maximum power at frequency 24.350 GHz is -41.13 dBm

Conclusion:

- There is no margin (~0.1 dB) to the FCC limit

3.1.7 Lower band edge – MIIT China

Test method:

1. Set the radio to:
   - TX mode
   - Modulated
   - Burst mode
   - Set the channel 0 (2.402 GHz)
2. Set the analyzer to:
   - Start frequency = 2.375 GHz
   - Stop frequency = 2.405 GHz
   - Ref amp = -20 dBm
   - Sweep time = 100 ms
   - Sweep point: 8001 pts
   - RBW = 1 MHz
   - VBW = 3 MHz
   - Detector = Max Hold
3. Software setting:
   - Set the `PA_RAMP_SEL` value to 0x02h (2 us)
   - Modification: `XCVR_TX_DIG_PA_CTRL_PA_RAMP_SEL` (2) in the `nxp_xcvr_common_config.c` file

Results:

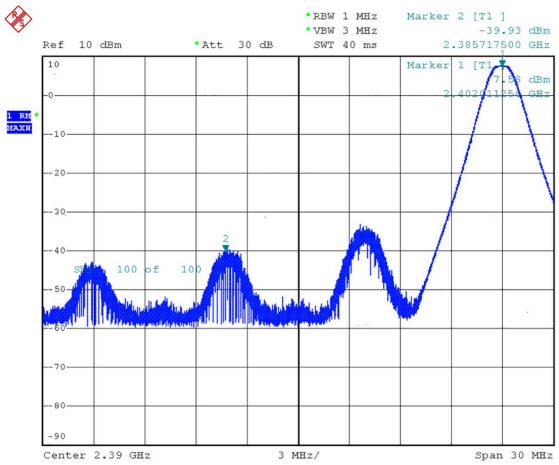


Figure 31. Lower band edge – Channel 0

Conclusion:

- The lower band edge test passes the Bluetooth SIG (MIIT-China) certification
- There is no margin to the Bluetooth SIG (MIIT-China) limit (-40 dBm below 2.39 GHz)

3.1.8 Upper band edge – MIIT China

Test method:

1. Set the radio to:
   - TX mode
   - Modulated
   - Burst mode
   - Set the channel 39 (2.48 GHz)
   - Set the power to 3 (-12 dBm)
2. Set the analyzer to:
   - Start frequency = 2.477 GHz
   - Stop frequency =2.507 GHz
   - Ref amp=-20 dBm
   - Sweep time=40 ms
   - Sweep point: 8001 pts
   - RBW = 1 MHz
   - VBW = 3 MHz
   - Detector = Max Hold
3. Software setting:
   - Set the `PA_RAMP_SEL` value to 0x03h (4 us)
   - Modification: `XCVR_TX_DIG_PA_CTRL_PA_RAMP_SEL` (2) in the `nxp_xcvr_common_config.c` file

Results:

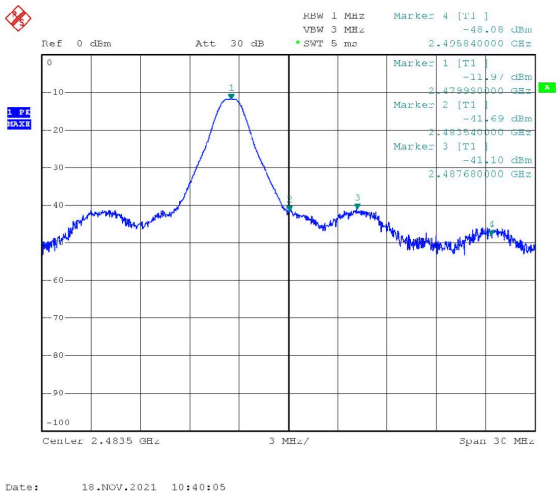


Figure 32. Upper band edge – Channel 39

Conclusion:

- The upper band edge test passes the Bluetooth SIG (MIIT-China) certification
- There is no margin to the Bluetooth SIG (MIIT-China) limit (-40 dBm higher than 2.4835 GHz)

3.1.9 Upper band edge (FCC ANSI C63.10, 558074 D01 DTS)

Test method:

1. Set the radio to:
   - TX mode
   - Modulated (1 Msps, 2 Msps, 500 ksps, 125 ksps)
   - Continuous mode
   - Maximum RF output power +10 dBm
2. Set the analyzer to:
   - Start frequency = 2.475 GHz
   - Stop frequency = 2.485 GHz
   - Ref amp = -20 dBm
   - Sweep time = 100 ms
   - RBW = 100 kHz
   - VBW = 300 kHz
   - Detector = Average
   - Average mode: Power
   - Number of sweeps = 100
   - Set the channel 39 GHz to 2.48 GHz

Results:

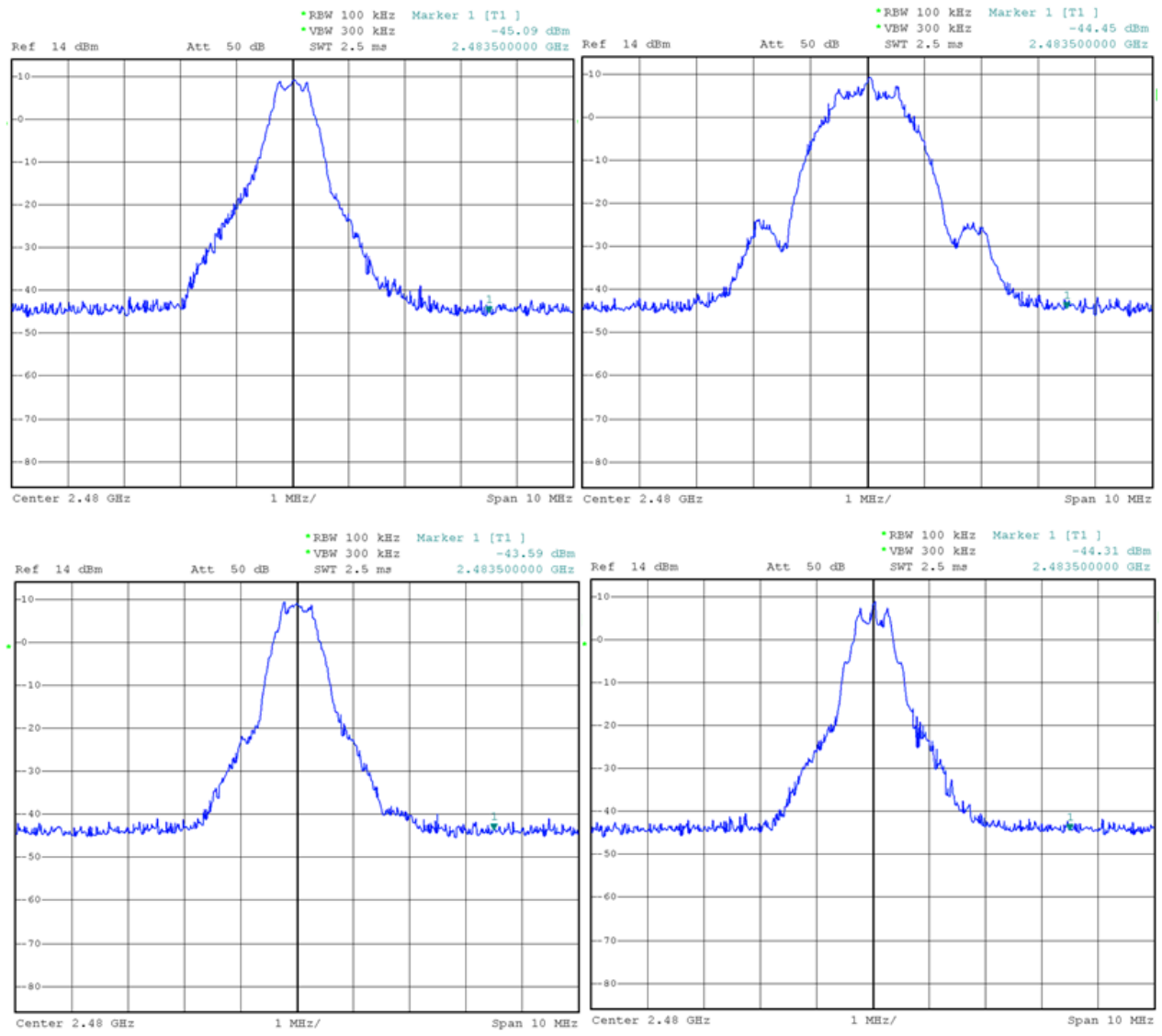


Figure 33. Upper band edge - Channel 39

Results:

Table 16. Modulation

Modulation	1 Msps	2 Msps	500 ksps	125 ksps
Level at 2.4835 GHz	-45.09 dBm	-44.45 dBm	-43.59 dBm	-44.31 dBm

- FCC limit: < -41.15 dBm

Conclusion:

- The upper band edge test passes the FCC certification with < 41.15 dBm at 2.4835 GHz with a minimum of 2 dB margin

3.1.10 Out of band (ETSI 300 328 chapter 5.4.8.2.1)

Test method:

1. Set the radio to:
   - TX mode
   - Modulated
   - Continuous mode
   - Channel 39 RF output power must be set to +0 dBm (Connectivity test value = power 10)
2. Set the analyzer to:
   - Start frequency = 2.475 GHz
   - Stop frequency = 2.485 GHz
   - Ref amp = -20 dBm
   - Sweep time = 100 ms
   - RBW = 1 MHz
   - VBW = 3 MHz
   - Detector = RMS
   - Average mode = Power
   - Number of Sweeps = 100
   - Set the channel 39 GHz to 2.48 GHz

Results:

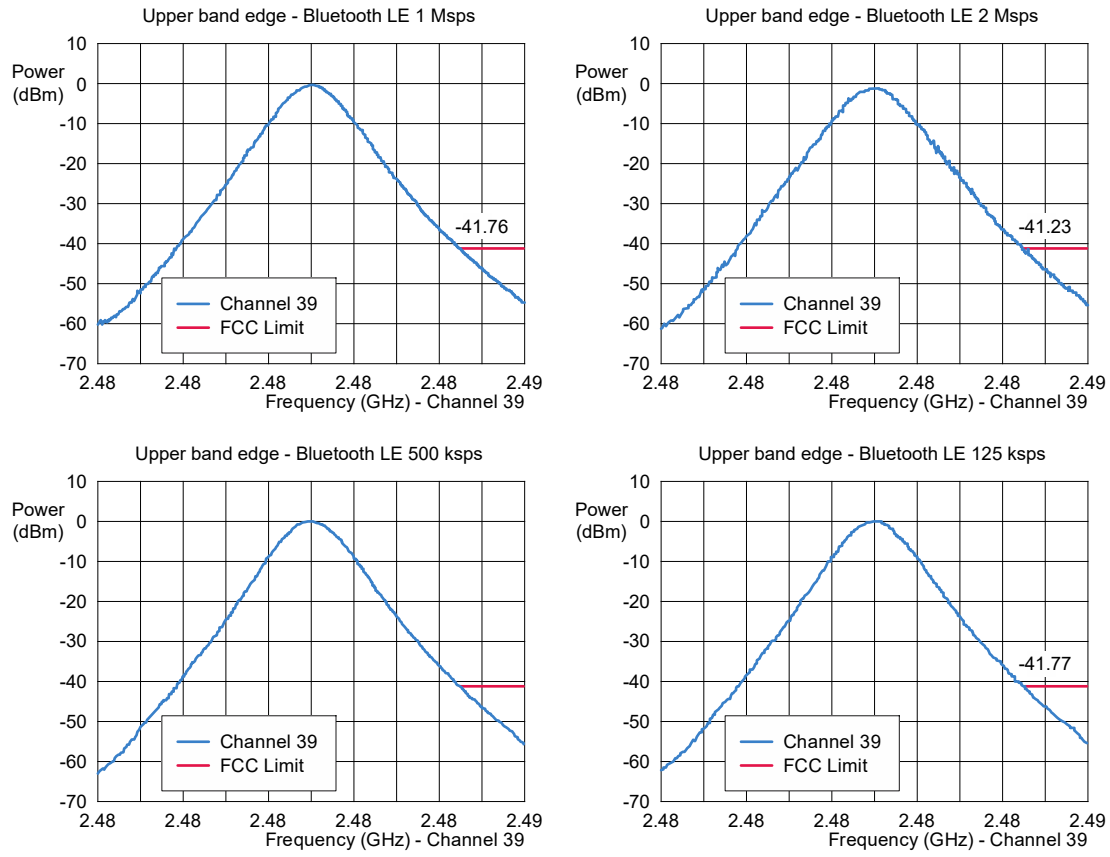


Figure 34. Upper band edge - channel 39

Conclusion:

- The upper band edge test passes the FCC certification on -41.15 dBm at 2.4835 GHz
  - There is no margin by setting the RF output power to +0 dBm to the FCC limit
  - To fix your margin, decrease the RF output level to the channel 0

3.1.11 Maximum TX output power

A CMW equipment is used to measure the PER at the maximum TX output power.

Flashed software: A specific binary is flashed: `hci_bb.bin`, which is available in the Bluetooth application examples.

Test method:

- Generator for the desired signal: CMW R&S
- Criterion: PER < 30.8 % with 1500 packets
- Channels under test: 0, 19, and 39

Result:

TP/TRM-LE/CA/BV-01-C [Output power at 1 Ms/s]	Lower Limit	Upper Limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-01-C [Output power at 1 Ms/s] @ Payload length: 37, Statistic Count: 1					
Channel 0					
Frequency Deviation df1 Average	225	275	250.10	kHz	Passed
Frequency Deviation df2 99%	185	---	204.84	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	---	0.84	---	Passed
Channel 19					
Frequency Deviation df1 Average	225	275	256.61	kHz	Passed
Frequency Deviation df2 99%	185	---	209.14	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	---	0.84	---	Passed
Channel 39					
Frequency Deviation df1 Average	225	275	250.52	kHz	Passed
Frequency Deviation df2 99%	185	---	210.94	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	---	0.86	---	Passed

Figure 35. Bluetooth LE 1 Msps

Conclusion:

- In line with the expected results

3.1.12 Bluetooth LE TX output spectrum

A CMW equipment is used to measure the adjacent channel power.

Flashed software: A specific binary is flashed: `hci_bb.bin`, which is available in the Bluetooth application examples.

Test method:

- Generator for the desired signal: CMW R&S
- Criterion: PER < 30.8 % with 1500 packets
- Channels under test: 3, 19, and 37

Result:

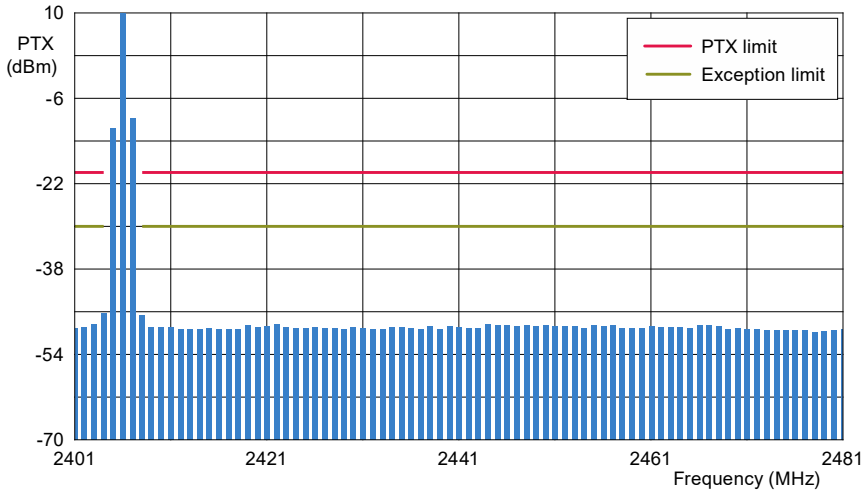


Figure 36. Channel 3, 1 Msps

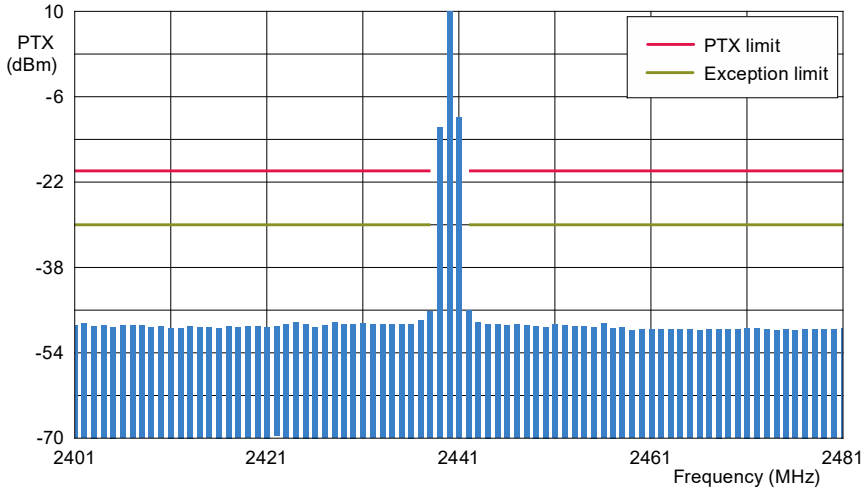


Figure 37. Channel 19, 1 Msps

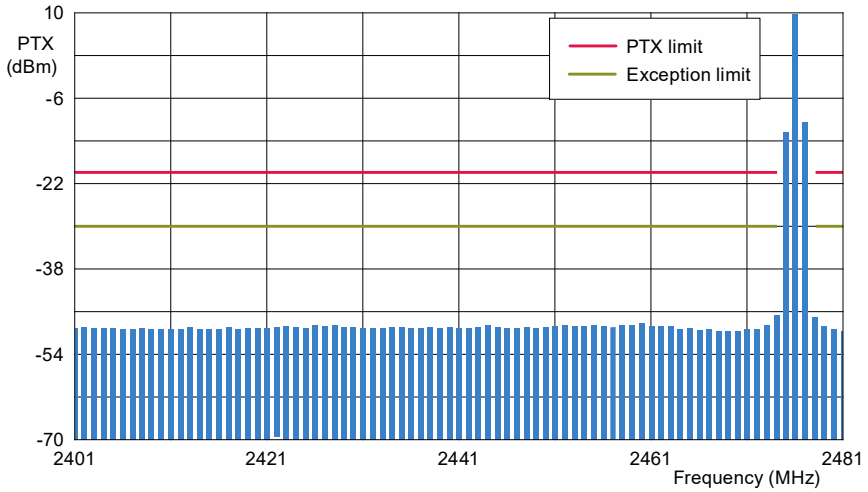


Figure 38. Channel 37, 1 Msps

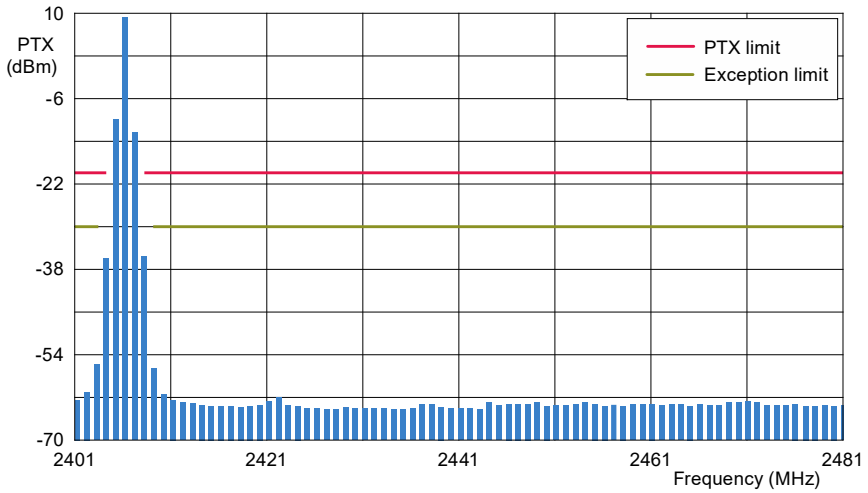


Figure 39. Channel 2, 2 Msps

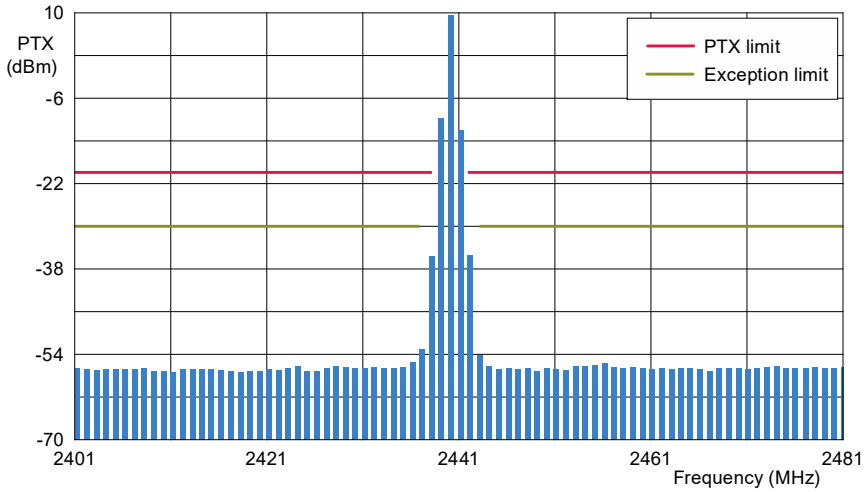


Figure 40. Channel 19, 2 Msps

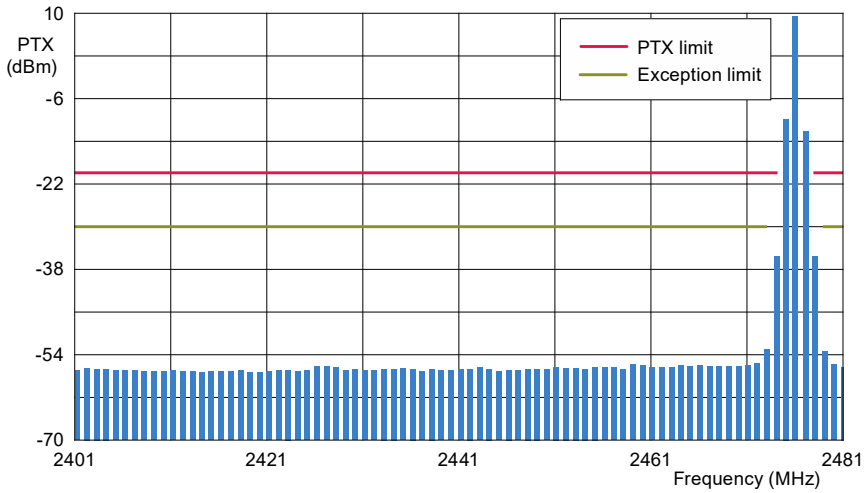


Figure 41. Channel 37, 2 Msps

3.1.13 Modulation characteristics

A CMW equipment is used to measure the frequency deviation df1 and df2.

Flashed software: A specific binary is flashed: `hci_bb.bin`, which is available in the Bluetooth application examples.

Test method:

- Generator for the desired signal: CMW R&S
- Criterion: PER < 30.8 % with 1500 packets
- Channels under test: 0, 19, and 39

Result:

TP/TRM-LE/CA/BV-05-C [Modulation Characteristics at 1 Ms/s]	Lower Limit	Upper Limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-05-C [Modulation Characteristics at 1 Ms/s] @ Payload length: 37, Statistic Count: 10					
Channel 0					
Frequency Deviation df1 Average	225	275	250.10	kHz	Passed
Frequency Deviation df2 99%	185	---	204.84	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	---	0.84	---	Passed
Channel 19					
Frequency Deviation df1 Average	225	275	256.61	kHz	Passed
Frequency Deviation df2 99%	185	---	209.14	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	---	0.84	---	Passed
Channel 39					
Frequency Deviation df1 Average	225	275	250.52	kHz	Passed
Frequency Deviation df2 99%	185	---	210.94	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	---	0.86	---	Passed

Figure 42. Modulation characteristics at 1 Msps

TP/TRM-LE/CA/BV-10-C [Modulation Characteristics at 2 Ms/s]	Lower Limit	Upper Limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-10-C [Modulation Characteristics at 2 Ms/s] @ Payload length: 37, Statistic Count: 10					
Channel 0					
tblContinuation_7_1					
Frequency Deviation df1 Average	450	550	506.34	kHz	Passed
tblContinuation_7_2					
Frequency Deviation df2 99%	370	---	400.70	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	---	0.81	---	Passed
Channel 19					
tblContinuation_7_3					
Frequency Deviation df1 Average	450	550	500.85	kHz	Passed
tblContinuation_7_4					
Frequency Deviation df2 99%	370	---	402.89	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	---	0.83	---	Passed
Channel 39					
tblContinuation_7_5					
Frequency Deviation df1 Average	450	550	505.42	kHz	Passed
tblContinuation_7_6					
Frequency Deviation df2 99%	370	---	402.30	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	---	0.82	---	Passed

Figure 43. Modulation characteristics at 2 Msps

TP/TRM-LE/CA/BV-13-C [Modulation Characteristics, LE Coded (S=8)]	Lower Limit	Upper Limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-13-C [Modulation Characteristics, LE Coded (S=8)] @ Payload length: 37, Statistic Count: 10					
Channel 0					
tblContinuation_9_1					
Frequency Deviation df1 Average	225	275	252.43	kHz	Passed
tblContinuation_9_2					
Frequency Deviation df1 99%	185	---	242.22	kHz	Passed
Channel 19					
tblContinuation_9_3					
Frequency Deviation df1 Average	225	275	250.74	kHz	Passed
Frequency Deviation df1 99%	185	---	241.82	kHz	Passed
Channel 39					
tblContinuation_9_4					
Frequency Deviation df1 Average	225	275	251.84	kHz	Passed
Frequency Deviation df1 99%	185	---	241.22	kHz	Passed

Figure 44. Modulation characteristics at LE coded (S8)

Conclusion:

- Good margins, in line with the expected results

3.1.14 Carrier frequency offset and drift

A CMW equipment is used to measure the frequency deviation df1 and df2.

Flashed software: A specific binary is flashed: `hci_bb.bin`, which is available in the Bluetooth application examples.

Test method:

- Generator for the desired signal: CMW270 R&S
- Criterion: PER < 30.8 % with 1500 packets
- Channels under test: 0, 19, and 39

Result:

TP/TRM-LE/CA/BV-06-C [Carrier frequency offset and drift at 1 Ms/s]	Lower Limit	Upper Limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-06-C [Carrier frequency offset and drift at 1 Ms/s] @ Payload length: 37, Statistic Count: 10					
Channel 0					
Frequency Accuracy	-150.00	150.00	7.31	kHz	Passed
Frequency Drift	-50.00	50.00	3.32	kHz	Passed
Max Drift Rate	-20.00	20.00	1.43	kHz/ 50 µs	Passed
Frequency Offset	-150.00	150.00	8.82	kHz	Passed
Initial Frequency Drift	-23.00	23.00	2.20	kHz	Passed
Channel 19					
Frequency Accuracy	-150.00	150.00	8.22	kHz	Passed
Frequency Drift	-50.00	50.00	1.96	kHz	Passed
Max Drift Rate	-20.00	20.00	1.44	kHz/ 50 µs	Passed
Channel 39					
Frequency Accuracy	-150.00	150.00	7.87	kHz	Passed
Frequency Drift	-50.00	50.00	2.06	kHz	Passed
Max Drift Rate	-20.00	20.00	1.47	kHz/ 50 µs	Passed
Frequency Offset	-150.00	150.00	9.19	kHz	Passed
Initial Frequency Drift	-23.00	23.00	1.70	kHz	Passed

Figure 45. Carrier frequency offset and drift at 1 Msps

TP/TRM-LE/CA/BV-12-C [Carrier frequency offset and drift at 2 Ms/s]	Lower Limit	Upper Limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-12-C [Carrier frequency offset and drift at 2 Ms/s] @ Payload length: 37, Statistic Count: 10					
Channel 0					
tblContinuation_8_1					
Frequency Accuracy	-150.00	150.00	-24.33	kHz	Passed
Frequency Drift	-50.00	50.00	-4.54	kHz	Passed
Max Drift Rate	-20.00	20.00	-2.25	kHz/ 50 µs	Passed
Frequency Offset	-150.00	150.00	-27.50	kHz	Passed
Initial Frequency Drift	-23.00	23.00	-2.49	kHz	Passed
Channel 19					
tblContinuation_8_2					
Frequency Accuracy	-150.00	150.00	-24.48	kHz	Passed
Frequency Drift	-50.00	50.00	-5.12	kHz	Passed
Max Drift Rate	-20.00	20.00	-2.69	kHz/ 50 µs	Passed
Frequency Offset	-150.00	150.00	-27.86	kHz	Passed
Initial Frequency Drift	-23.00	23.00	-2.69	kHz	Passed
Channel 39					
tblContinuation_8_3					
Frequency Accuracy	-150.00	150.00	-24.91	kHz	Passed
Frequency Drift	-50.00	50.00	-5.47	kHz	Passed
Max Drift Rate	-20.00	20.00	-1.91	kHz/ 50 µs	Passed
Frequency Offset	-150.00	150.00	-28.63	kHz	Passed
Initial Frequency Drift	-23.00	23.00	-2.73	kHz	Passed

Figure 46. Carrier frequency offset and drift at 2 Msps

TP/TRM-LE/CA/BV-14-C [Carrier frequency offset and drift, LE Coded (S=8)]	Lower Limit	Upper Limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-14-C [Carrier frequency offset and drift, LE Coded (S=8)] @ Payload length: 37, Statistic Count: 10					
tblContinuation_10_1					
Channel 0					
tblContinuation_10_2					
Frequency Accuracy	-150.00	150.00	-25.51	kHz	Passed
Frequency Drift	-50.00	50.00	-2.66	kHz	Passed
Max Drift Rate	-19.20	19.20	-2.59	kHz/ 50 µs	Passed
Frequency Offset	-150.00	150.00	-26.71	kHz	Passed
Channel 19					
tblContinuation_10_3					
Frequency Accuracy	-150.00	150.00	-25.92	kHz	Passed
Frequency Drift	-50.00	50.00	-3.04	kHz	Passed
Max Drift Rate	-19.20	19.20	-2.71	kHz/ 50 µs	Passed
Frequency Offset	-150.00	150.00	-27.24	kHz	Passed
Channel 39					
tblContinuation_10_4					
Frequency Accuracy	-150.00	150.00	-26.35	kHz	Passed
Frequency Drift	-50.00	50.00	-3.00	kHz	Passed
Max Drift Rate	-19.20	19.20	-3.00	kHz/ 50 µs	Passed
Frequency Offset	-150.00	150.00	-27.66	kHz	Passed

Figure 47. Carrier frequency offset and drift at LR (S=8)

Conclusion:

- Good margins, in line with the expected results

3.2 RX tests

This section lists the details about RX tests.

3.2.1 Test setup

Figure 48 to Figure 51, shows the conducted RX test setups.

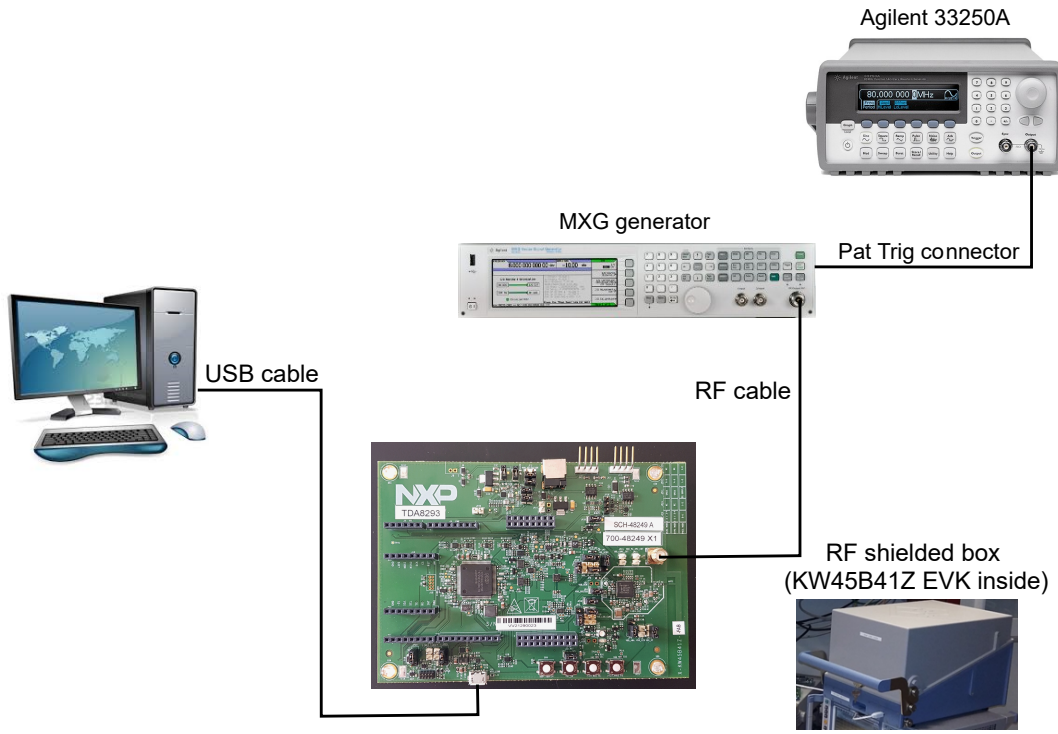


Figure 48. Conducted RX test setup for sensitivity with RF generator and faraday box

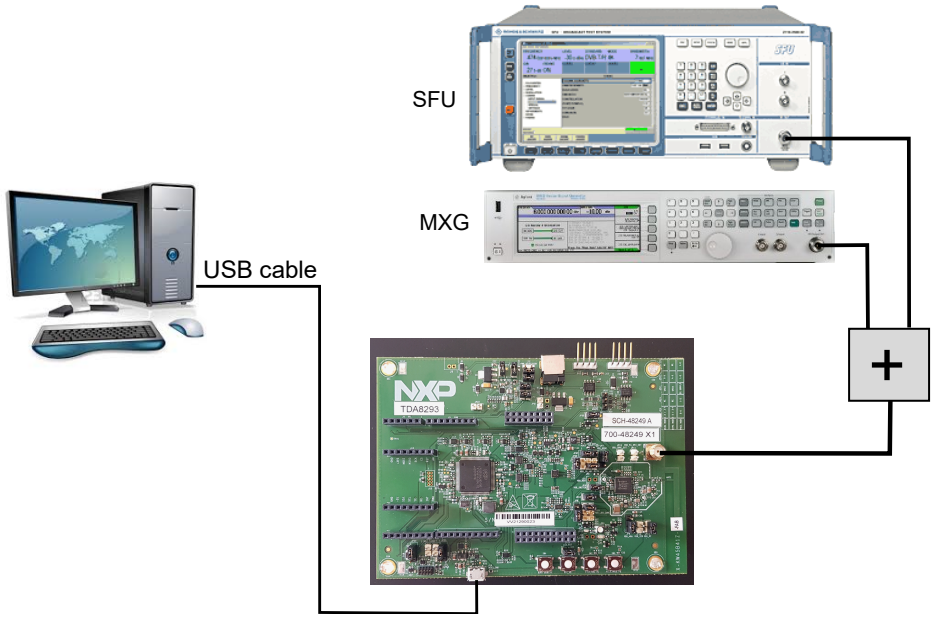


Figure 49. Conducted RX test setup for interference rejection

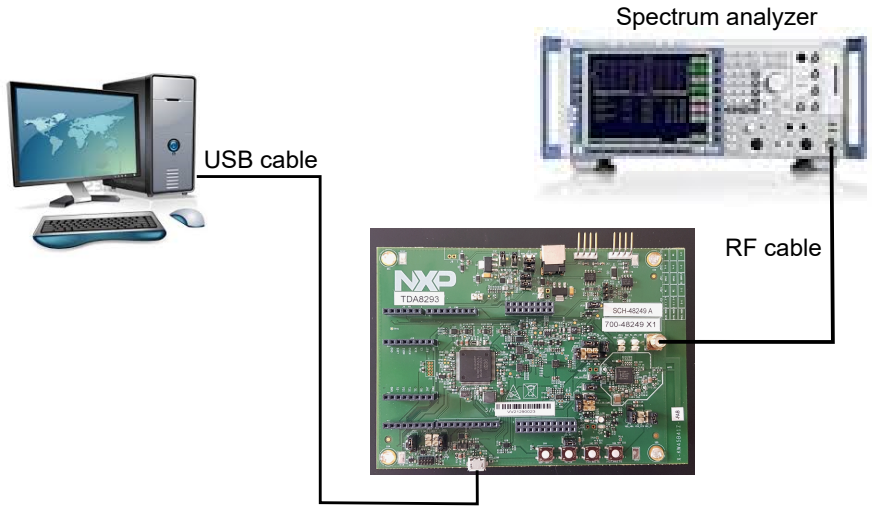


Figure 50. Conducted RX test setup for spurious

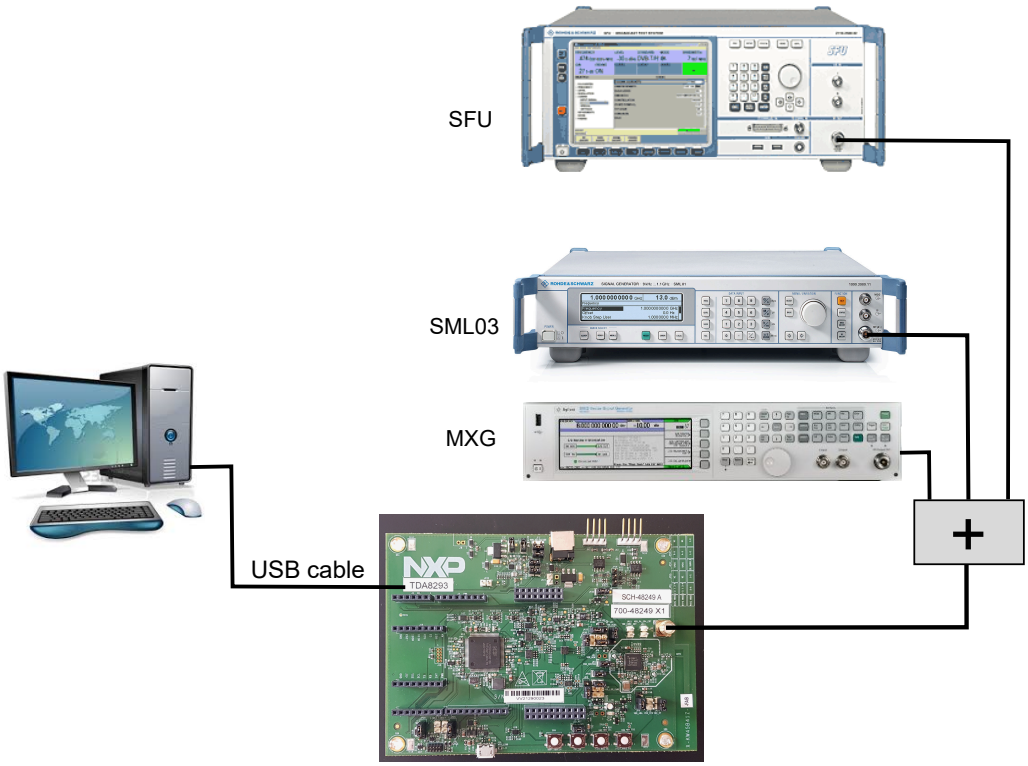


Figure 51. Conducted RX test setup for intermodulation performances

3.2.2 Sensitivity

3.2.2.1 With ARB generator

Flashed software: Connectivity test

Test method:

To remain immune to the external parasitic signals, KW45B41Z-EVK is kept in an RF-shielded box.

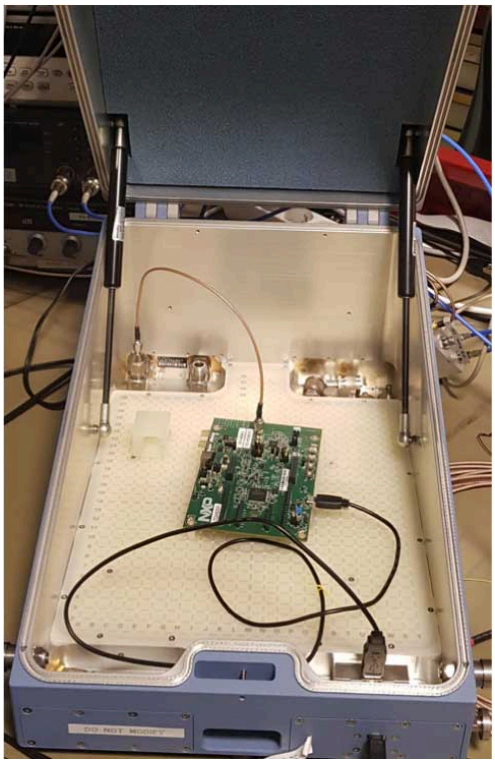


Figure 52. Sensitivity test

The generator, Agilent NX5181 MXG, is used in the ARB mode to generate a pattern of 1500 packets. The Tera Term window is used to control the module.

Test method is as follows:

1. Four modes are checked: 1 Msps, 2 Msps, LR (S=2), and LR (S=8)
2. Set it to channel 0
3. Connection is automatically established and PER is measured
4. Decrease the level of SFU at the RF input of the module until PER = 30.8 %
5. Repeat it up to channel 39

Results (@SMA connector):

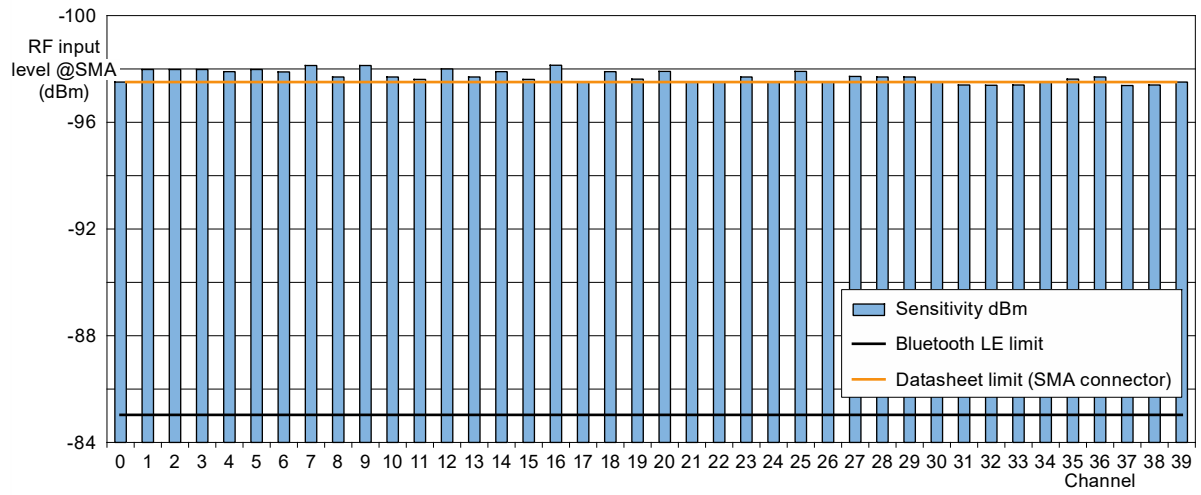


Figure 53. Sensitivity result – 1 Msps

- The best sensitivity is on channel 9: -98.1 dBm
- The lowest sensitivity is on channel 31: -97.4 dBm
- Delta over channels: 0.7 dB

KW45B41Z-EVK shows an average value of -97.7 dBm (1 Msps) at SMA connector.

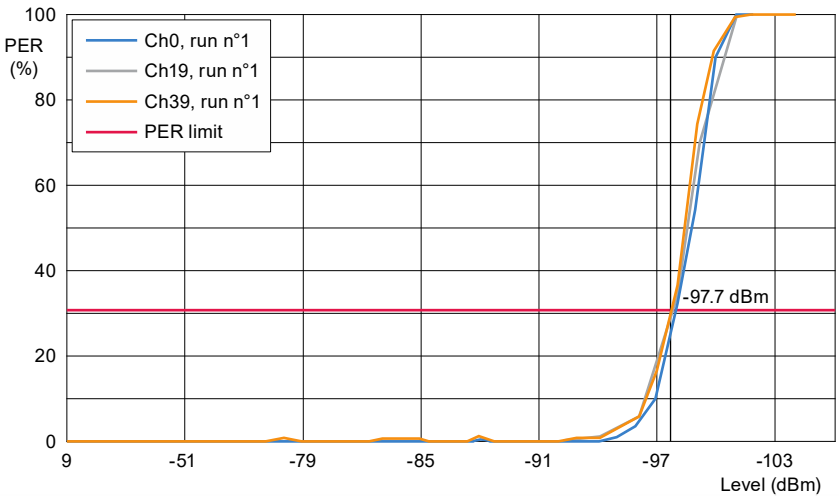


Figure 54. Sensitivity bathtub result – 1 Msps

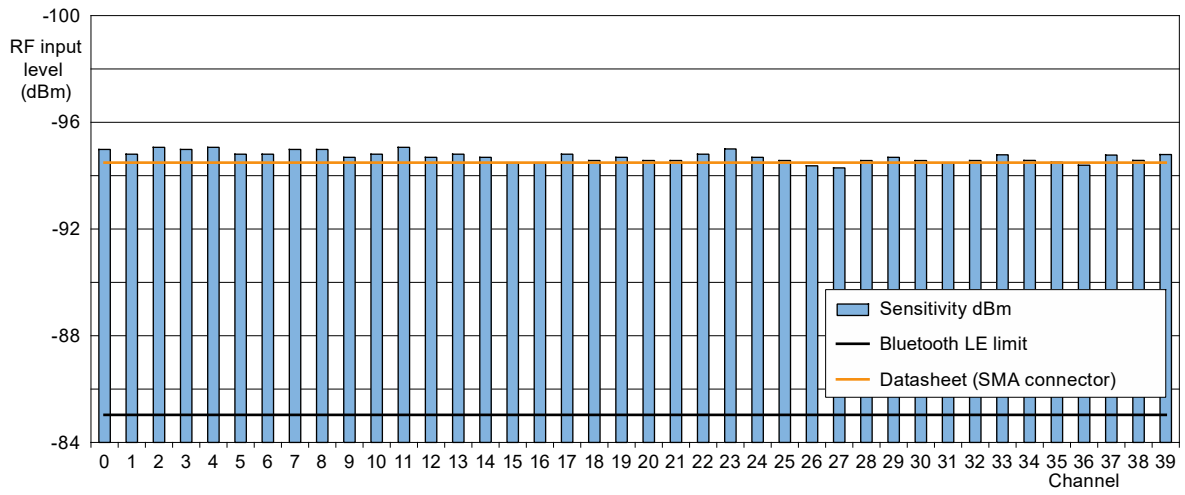


Figure 55. Sensitivity result – 2 Msps

- The best sensitivity is on channel 39: -95.9 dBm
- The lowest sensitivity is on channel 27: -95.2 dBm
- Delta over channels: 0.7 dB

KW45B41Z-EVK shows an average value of -94.7 dBm (2 Msps) at SMA connector.

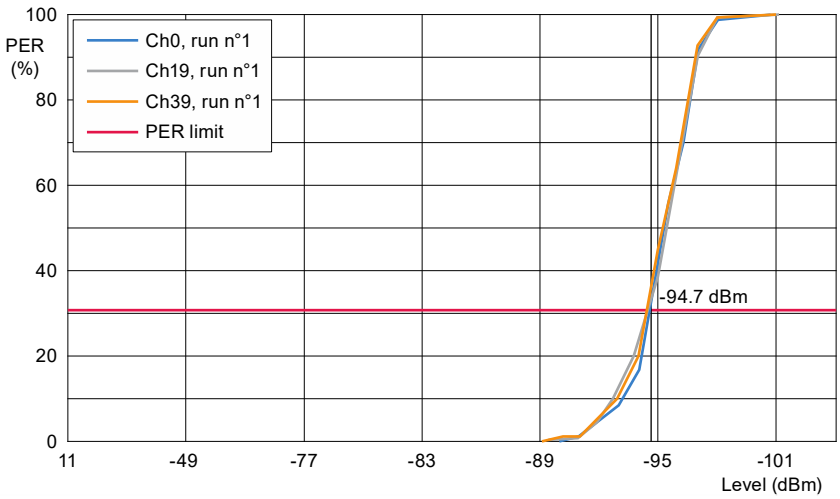


Figure 56. Sensitivity bathtub result – 2 Mbit/s

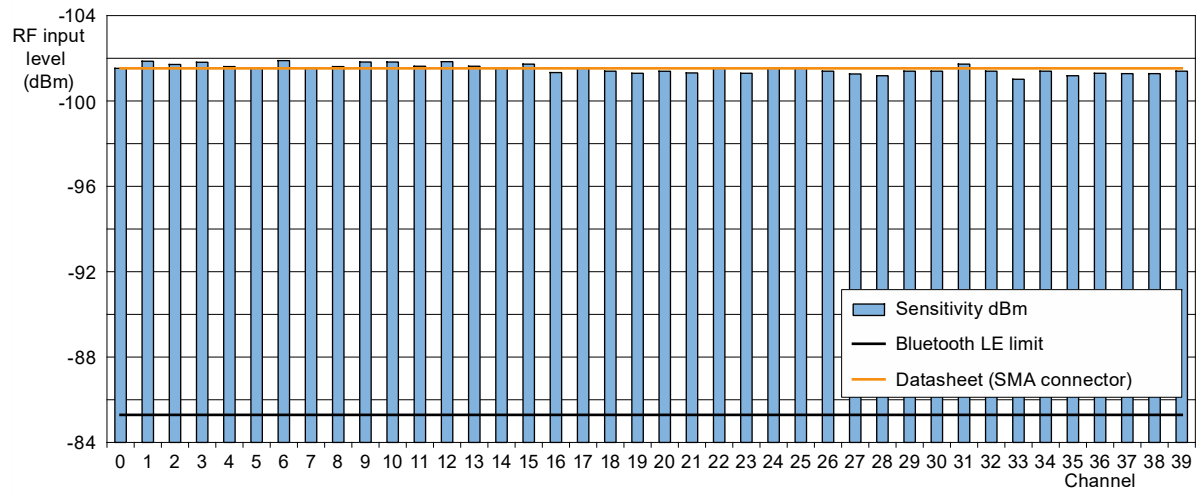


Figure 57. Sensitivity result – LR (S=2)

- The best sensitivity is on channel 31: -101.9 dBm
- The lowest sensitivity is on channel 13: -101.0 dBm
- Delta over channels: 0.9 dB

KW45B41Z-EVK shows an average value of -101.5 dBm (500 ksps) at SMA connector.

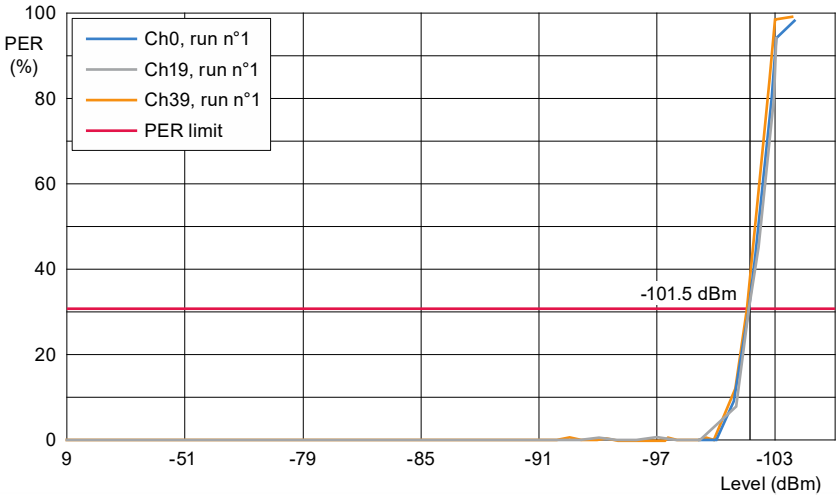


Figure 58. Sensitivity bathtub result – 500 kB/s

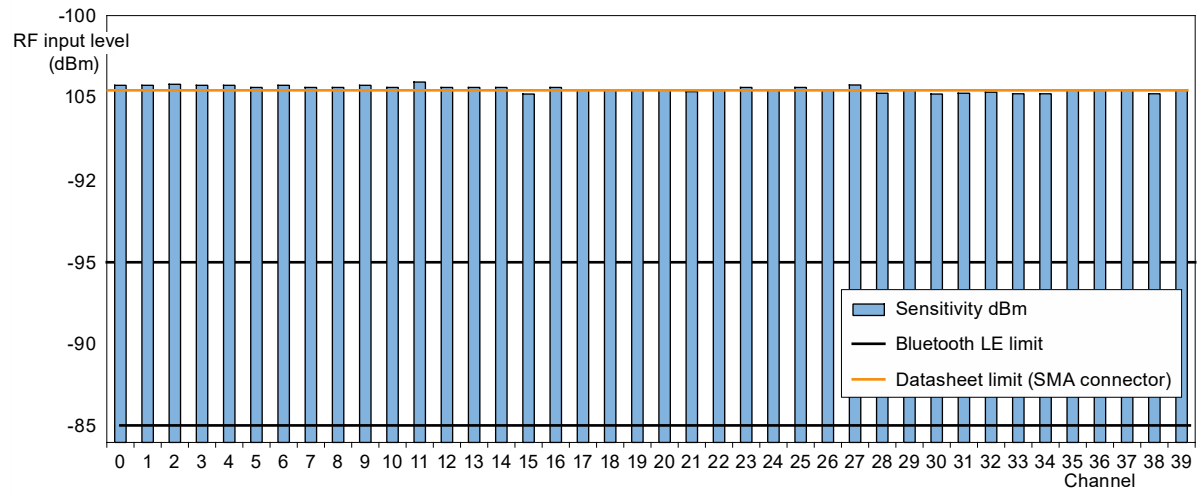


Figure 59. Sensitivity result – LR (S=8)

- The best sensitivity is on channel 11: -105.9 dBm
- The lowest sensitivity is on channel 28: -105.2 dBm
- Delta over channels: 0.7 dB

KW45B41Z-EVK shows an average value of -105.6 dBm (125 ksps) at SMA connector.

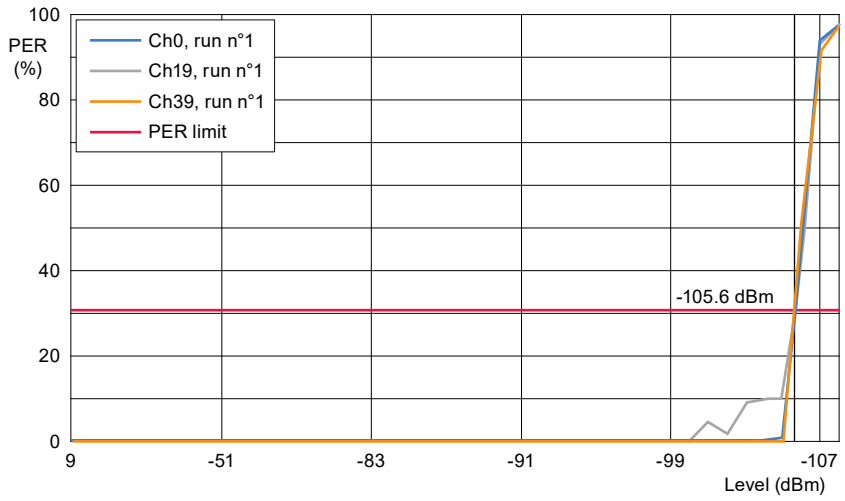


Figure 60. Sensitivity bathtub result – 125 kbit/s

Conclusion:

- KW45B41Z-EVK withstands an average sensitivity level of:
  - -97.7 dBm @1Msps (data sheet typical value: -97.65 dBm at the SMA connector)
  - -94.7 dBm @2Msps (data sheet typical value: -94.65 dBm at the SMA connector)
  - -101.5 dBm @LRS2 (data sheet typical value: -101.65 dBm at the SMA connector)
  - -105.6 dBm @LRS8 (data sheet typical value: -105.65 dBm at the SMA connector)

Note: *0.35 dB loss must be added to the sensitivity results to get the value at RF pin output (data sheet value).*

3.2.3 Receiver maximum input level

Flashed software: HCI_BB

Test method:

- The same test setup is used as with the sensitivity test is conducted
- The signal level is increased up to the PER = 30.8 % with 1500 packets

Results:

TP/RCV-LE/CA/BV-06-C [Maximum input signal level at 1 Ms/s]	Lower Limit	Upper Limit	Measured	Unit	Status
TP/RCV-LE/CA/BV-06-C [Maximum input signal level at 1 Ms/s] @ Payload length: 37, No. of Packets: 1500, RF Level: 0 dBm					
Channel 0					
tblContinuation_7_1					
PER	---	30.8	16.66667	%	Passed
Correct Packets	---	---	1250	---	Passed
Channel 19					
tblContinuation_7_2					
PER	---	30.8	16.53333	%	Passed
Correct Packets	---	---	1252	---	Passed
Channel 39					
tblContinuation_7_3					
PER	---	30.8	14.73333	%	Passed
Correct Packets	---	---	1279		Passed

Figure 61. Maximum input power – 1 Msps

TP/RCV-LE/CA/BV-12-C [Maximum input signal level at 2 Ms/s] @ Payload length: 37, No. of Packets: 1500, RF Level: 0 dBm					
tblContinuation_13_1					
Channel 0					
tblContinuation_13_2					
PER	---	30.8	12.80000	%	Passed
Correct Packets	---	---	1308	---	Passed
Channel 19					
tblContinuation_13_3					
PER	---	30.8	10.53333	%	Passed
Correct Packets	---	---	1342	---	Passed
Channel 39					
tblContinuation_13_4					
PER	---	30.8	12.86667	%	Passed
Correct Packets	---	---	1307		Passed

Figure 62. Maximum input power – 2 Msps

Conclusion:

- The results are limited by the maximum output power of the equipment

3.2.4 RX spurious

Flashed software: Connectivity test

Test method:

1. Set the radio to:
   - Receiver mode
   - Frequency: Channel 18
2. Set the analyzer to:
   - Ref amp = -20 dBm
   - Trace = Max Hold
   - Detector = Max Peak
   - Start/stop frequency: 30 MHz / 1 GHz
     - RBW = 100 kHz
     - VBW = 300 kHz
   - Then set the start/stop frequency: 1 GHz / 30 GHz
     - RBW = 1 MHz
     - VBW = 3 MHz

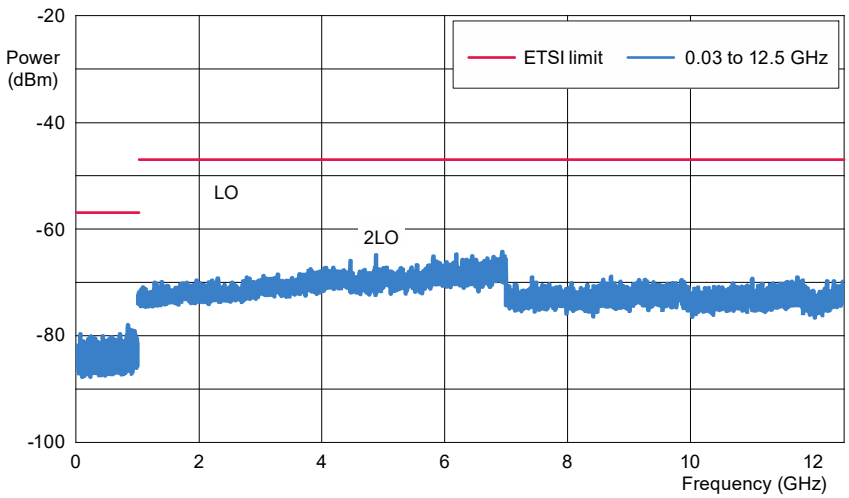


Figure 63. Conducted RX spurious 30 MHz – 12.5 GHz

Conclusion:

- There are no spurs above the spectrum analyzer noise floor, except for 2xLO
- More than 18 dB margin

3.2.5 Receiver interference rejection performances

3.2.5.1 Adjacent, Alternate, and Co-channel rejection – Bluetooth LE @1 Msps, @2 Msps, @500 ksps (LR S=2), @125 ksps (LR S=8)

The interferers are at the adjacent channel (+/-1 MHz, +/-2 MHz, +/-3 MHz) or co-channel.

The test is performed with only one interfering unmodulated signal at a time.

Test method:

- Generator for the desired signal: Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 30.8 % with 1500 packets
- The desired signal is set to -67 dBm; the interferer is increased until the PER threshold is reached
- Channels under test: 2, 19, and 37

Results:

	ch2				ch19				ch37			
	2406				2440				2476			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz	N-2MHz	N-1MHz	N+1MHz	N+2MHz	N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2402	2404	2408	2410	2436	2438	2442	2444	2472	2474	2478	2480
Interferer level (dBm)	-18.6	-62.1	-63.1	-17.1	-19.1	-63.1	-63.1	-17.1	-20.1	-62.1	-63.1	-17.1
Interferer level (C/I dB)	-48.4	-4.9	-3.9	-49.9	-47.9	-3.9	-3.9	-49.9	-46.9	-4.9	-3.9	-49.9
BLE 5. x limit (C/I dB)	-17	15	15	-17	-17	15	15	-17	-17	15	15	-17
Margin (dB)	31.4	19.9	18.9	32.9	30.9	18.9	18.9	32.9	29.9	19.9	18.9	32.9

	ch2		Co-channel	ch19		Co-channel	ch2		Co-channel
	2406		ch2	2440		ch19	2476		ch37
	N-3MHz	N+3MHz	2406	N-3MHz	N+3MHz	2440	N-3MHz	N+3MHz	2476
	2400	2412	N	2434	2446	N	2470	2482	N
Interferer level (dBm)	-10.1	-8.6	-70.1	-9.6	-8.6	-70.1	-9.6	-8.6	-70.1
Interferer level (C/I dB)	**-56.9**	**-58.4**	**3.1**	**-57.4**	**-58.4**	**3.1**	**-57.4**	**-58.4**	**3.1**
BLE 5. x limit (C/I dB)	-27	-27	21	-27	-27	21	-27	-27	21
Margin (dB)	29.9	31.4	17.9	30.4	31.4	17.9	30.4	31.4	17.9

Figure 64. Adjacent, alternate, and co-channel rejection

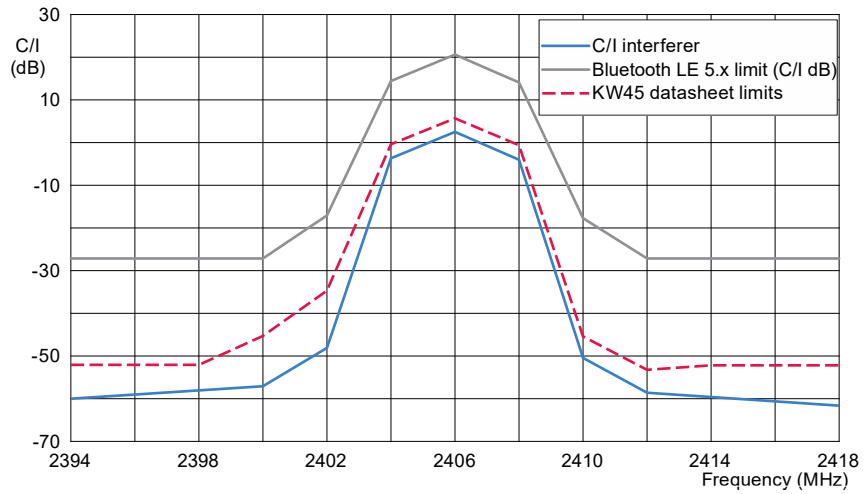


Figure 65. Adjacent, alternate, and co-channel rejection @channel 2

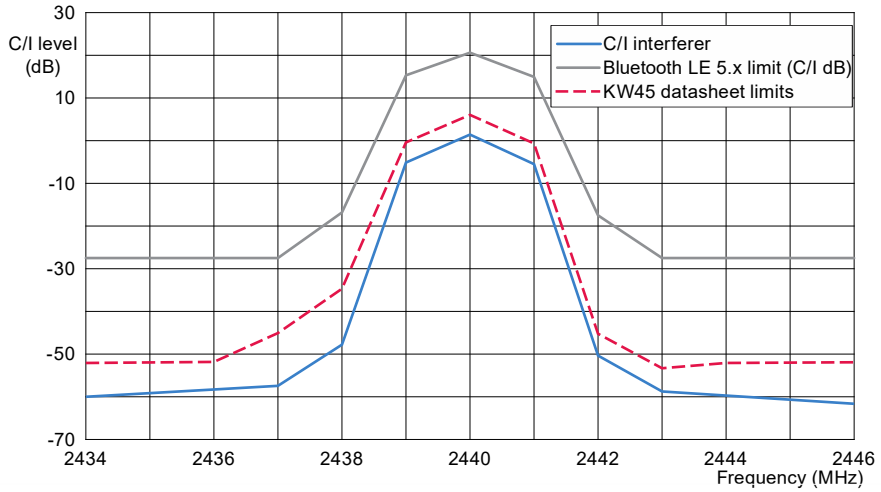


Figure 66. Adjacent, alternate, and co-channel rejection @channel 19

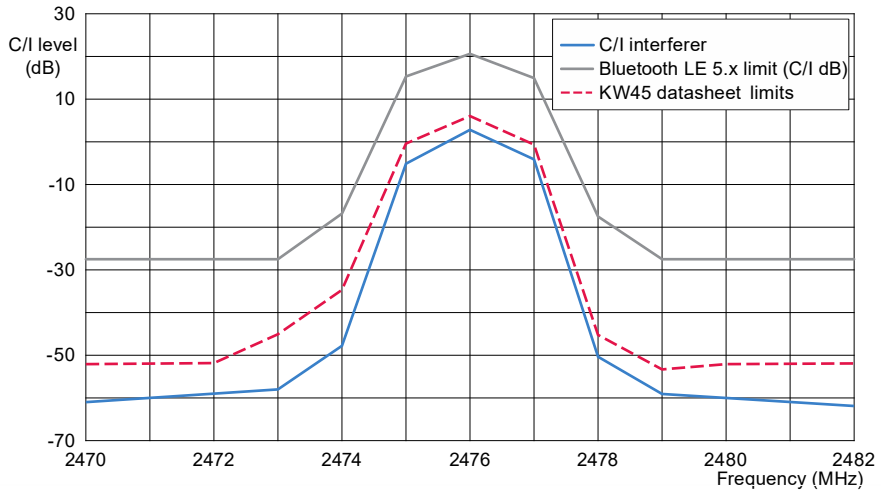


Figure 67. Adjacent, alternate, and co-channel rejection @channel 37

Conclusion:

- Good margin, in line with the expected results

Results: Bluetooth LE @ 2 Msps

	ch2				ch19				ch37			
	2406				2440				2476			
	N-4MHz	N-2MHz	N+2MHz	N+4MHz	N-4MHz	N-2MHz	N+2MHz	N+4MHz	N-4MHz	N-2MHz	N+2MHz	N+4MHz
	2398	2402	2410	2414	2432	2436	2444	2448	2468	2472	2480	2484
Interferer level (dBm)	-32.1	-57.6	-55.6	-22.1	-33.1	-59.6	-60.6	-22.1	-32.6	-58.1	-60.6	-21.6
Interferer level (C/I dB)	-34.9	-9.4	-11.4	-44.9	-33.9	-7.4	-6.4	-44.9	-34.4	-8.9	-6.4	-45.4
BLE 5. x limit (C/I dB)	-17	15	15	-17	-17	15	15	-17	-17	15	15	-17
Margin (dB)	17.9	24.4	26.4	27.9	16.9	22.4	21.4	27.9	17.4	23.9	21.4	28.4

	ch2		Co-channel	ch19		Co-channel	ch37		Co-channel
	2406		2406	2440		2440	2476		2476
	N-6MHz	N+6MHz	N	N-6MHz	N+6MHz	N	N-6MHz	N+6MHz	N
	2400	2412	2406	2434	2446	2440	2470	2482	2476
Interferer level (dBm)	-11.1	-11.1	-70.1	-11.1	-11.1	-70.1	-11.1	-10.6	-70.1
Interferer level (C/I dB)	**-55.9**	**-55.9**	**3.1**	**-55.9**	**-55.9**	**3.1**	**-55.9**	**-56.4**	**3.1**
BLE 5. x limit (C/I dB)	-27	-27	21	-27	-27	21	-27	-27	21
Margin (dB)	28.9	28.9	17.9	28.9	28.9	17.9	28.9	29.4	17.9

Figure 68. Adjacent, alternate, and co-channel rejection Bluetooth LE @ 2 Msps

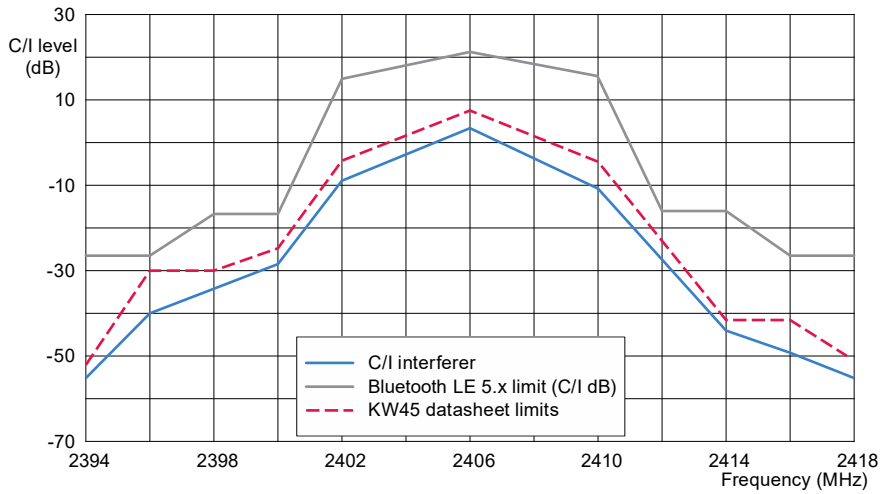


Figure 69. Adjacent, alternate, and co-channel rejection Bluetooth LE @ 2 Msps channel 2

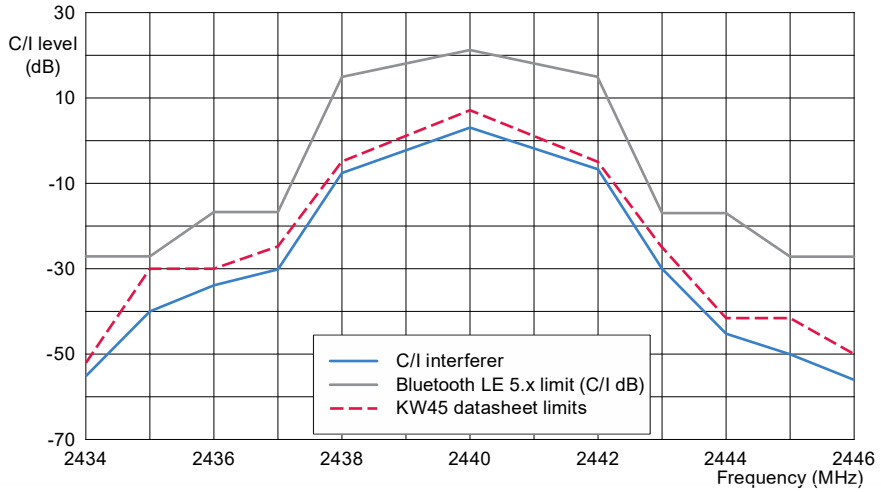


Figure 70. Adjacent, alternate, and co-channel rejection Bluetooth LE @ 2 Msps channel 19

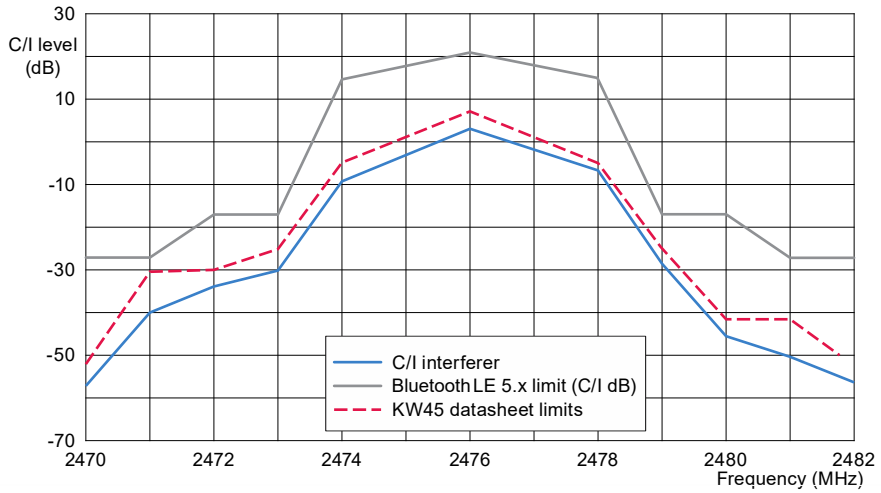


Figure 71. Adjacent, alternate, and co-channel rejection Bluetooth LE @ 2 Msps channel 37

Conclusion:

- Good margin, in line with the expected results

Results: Bluetooth LE @ 500 ksps (LR S=2)

	ch2				ch19				ch37			
	2406				2440				2476			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz	N-2MHz	N-1MHz	N+1MHz	N+2MHz	N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2402	2404	2408	2410	2436	2438	2442	2444	2472	2474	2478	2480
Interferer level (dBm)	-25.1	-55.1	-55.1	-16.6	-25.6	-55.1	-55.1	-11.6	-26.1	-55.6	-55.6	-12.1
Interferer level (C/I dB)	-41.9	-11.9	-11.9	-50.4	-41.4	-11.9	-11.9	-55.4	-40.9	-11.4	-11.4	-54.9
BLE 5. x limit (C/I dB)	-17	15	15	-17	-17	15	15	-17	-17	15	15	-17
Margin (dB)	24.9	26.9	26.9	33.4	24.4	26.9	26.9	38.4	23.9	26.4	26.4	37.9

	ch2		Co-channel	ch19		Co-channel	ch37		Co-channel
	2406		2406	2440		2440	2476		2476
	N-3MHz	N+3MHz	N	N-3MHz	N+3MHz	N	N-3MHz	N+3MHz	N
	2400	2412	2406	2434	2446	2440	2470	2482	2476
Interferer level (dBm)	-15.1	-4.6	-64.6	-12.1	-7.1	-64.6	-12.1	-7.6	-64.1
Interferer level (C/I dB)	**-51.9**	**-62.4**	**-2.4**	**-54.9**	**-59.9**	**-2.4**	**-54.9**	**-59.4**	**-2.9**
BLE 5. x limit (C/I dB)	-27	-27	21	-27	-27	21	-27	-27	21
Margin (dB)	24.9	35.4	23.4	27.9	32.9	23.4	27.9	32.4	23.9

Figure 72. Adjacent, alternate, and co-channel rejection Bluetooth LE @ 500 ksps (LR S=2)

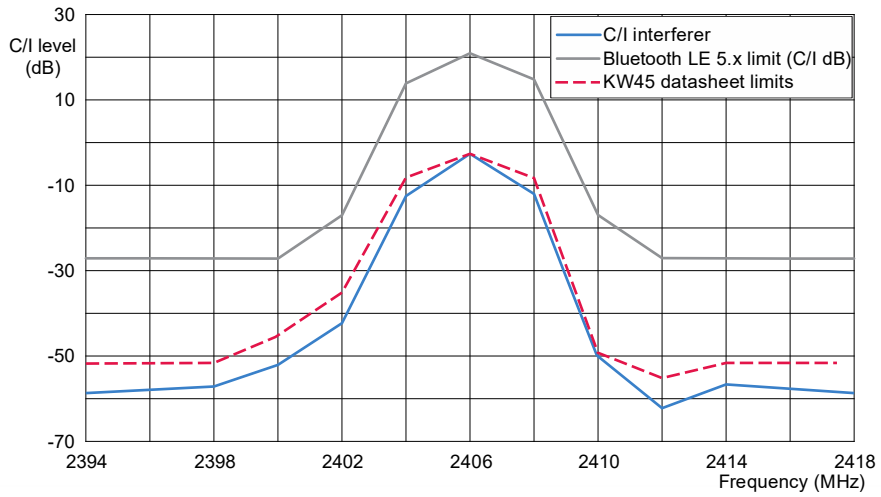


Figure 73. Adjacent, alternate, and co-channel rejection Bluetooth LE @ 500 ksps (LR S=2) channel 2

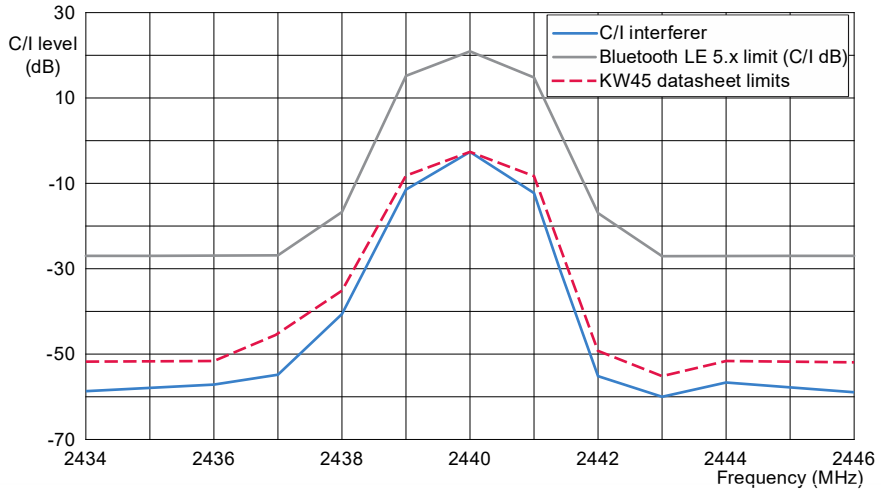


Figure 74. Adjacent, alternate, and co-channel rejection Bluetooth LE @ 500 ksps (LR S=2) channel 19

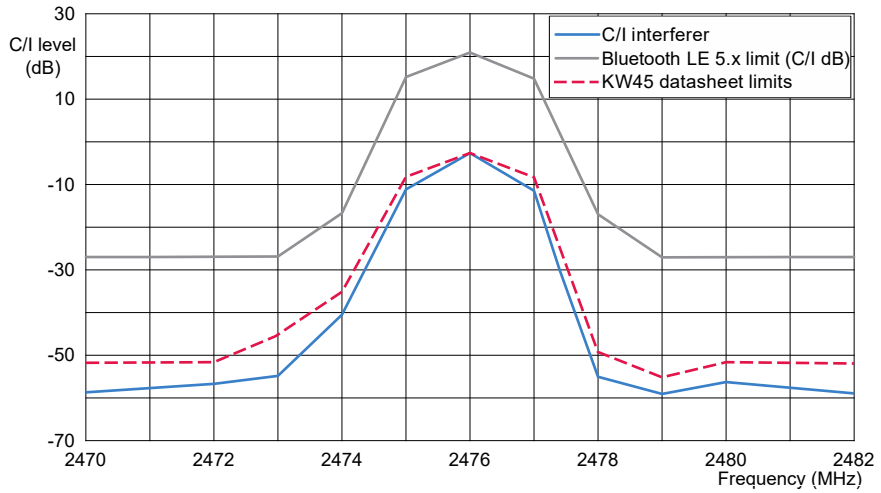


Figure 75. Adjacent, alternate, and co-channel rejection Bluetooth LE @ 500 ksps (LR S=2) channel 37

Conclusion:

- Good margin, in line with the expected results

Results: Bluetooth LE @125 ksps (LR S=8).

	ch2				ch19				ch37			
	2406				2440				2476			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz	N-2MHz	N-1MHz	N+1MHz	N+2MHz	N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2402	2404	2408	2410	2436	2438	2442	2444	2472	2474	2478	2480
Interferer level (dBm)	-27.1	-58.6	-58.6	-17.6	-28.1	-59.1	-58.6	-16.6	-29.6	-58.1	-58.6	-16.6
Interferer level (C/I dB)	-39.9	-8.4	-8.4	-49.4	-38.9	-7.9	-8.4	-50.4	-37.4	-8.9	-8.4	-50.4
BLE 5. x limit (C/I dB)	-17	15	15	-17	-17	15	15	-17	-17	15	15	-17
Margin (dB)	22.9	23.4	23.4	32.4	21.9	22.9	23.4	33.4	20.4	23.9	23.4	33.4

	ch2		Co-channel	ch19		Co-channel	ch37		Co-channel
	2406		ch2	2440		ch19	2476		ch37
	N-3MHz	N+3MHz	2406	N-3MHz	N+3MHz	2440	N-3MHz	N+3MHz	2476
	2400	2412	N	2434	2446	N	2470	2482	N
Interferer level (dBm)	-12.6	-11.1	-65.1	-12.6	-9.1	-65.1	-12.6	-11.1	-65.1
Interferer level (C/I dB)	**-54.4**	**-55.9**	**-1.9**	**-54.4**	**-57.9**	**-1.9**	**-54.4**	**-55.9**	**-1.9**
BLE 5. x limit (C/I dB)	-27	-27	21	-27	-27	21	-27	-27	21
Margin (dB)	27.4	28.9	22.9	27.4	30.9	22.9	27.4	28.9	22.9

Figure 76. Adjacent, alternate, and co-channel rejection Bluetooth LE @ 125 ksps (LR S=8)

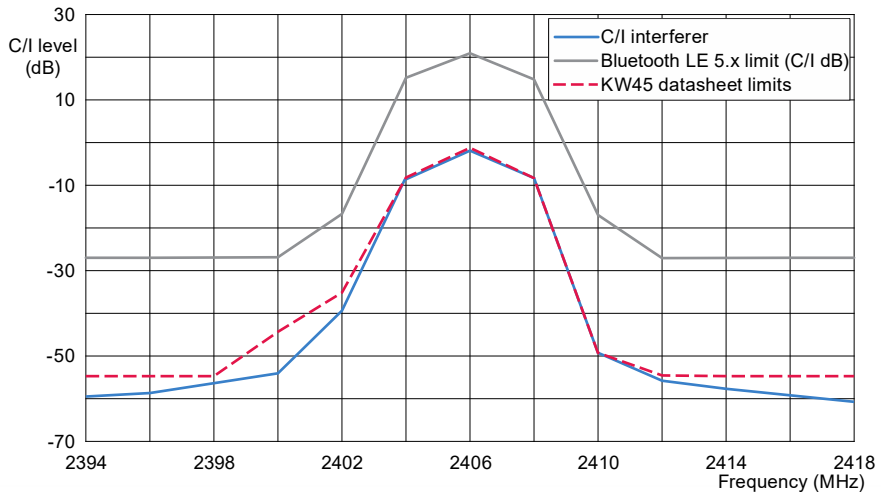


Figure 77. Adjacent, alternate, and co-channel rejection Bluetooth LE @ 125 ksps (LR S=8) channel 2

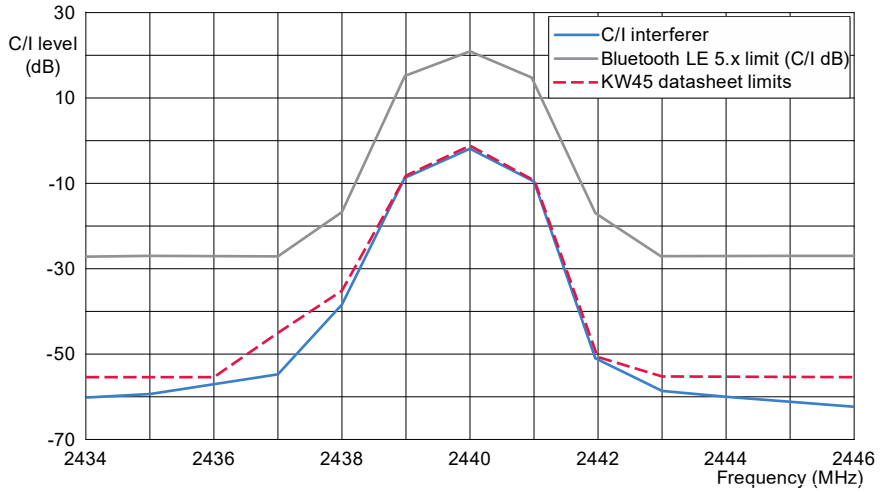


Figure 78. Adjacent, alternate, and co-channel rejection Bluetooth LE @ 125 ksps (LR S=8) channel 19

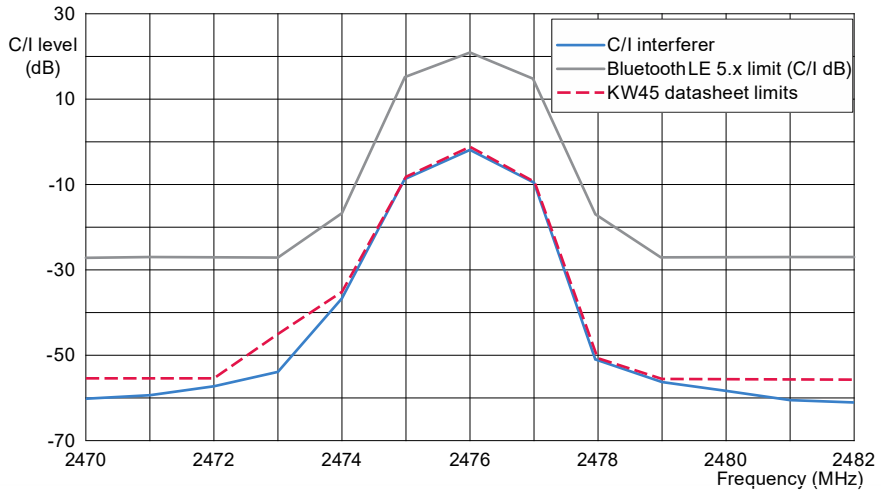


Figure 79. Adjacent, alternate, and co-channel rejection Bluetooth LE @ 125 ksps (LR S=8) channel 37

Conclusion:

- Good margin, in line with the expected results

3.2.5.2 Receiver blocking

The blocking interferers are positioned at the out of band channels depending on the receiver category.

3.2.5.2.1 Receiver category 1 - Bluetooth LE-1 Msps

The test is performed with only one interfering signal at a time, for more details refer to the 300.328 2.1.1 chapter 4.3.1.12.4.2.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE - 1 Msps): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The desired signal is set to Pmin +6 dB (-82 dBm); the interferer is increased until the PER threshold is reached
- Channels under test: 0 and 39

Result:

	ch0	**ch0**	**ch39**	**ch39**
	2402	2402	2480	2480
	Low	**High**	**Low**	**High**
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-16.1	-18.1	-17.1	-19.1
300 328 limit (dBm)	-53	-53	-53	-53
Margin (dB)	36.9	34.9	35.9	33.9

	ch0	**ch0**	**ch0**	**ch39**	**ch39**	**ch39**
	2402	2402	2402	2480	2480	2480
	Low	**Low**	**Low**	**Low**	**Low**	**Low**
	2300	2330	2360	2300	2330	2360
Interferer level (dBm)	-16.1	-16.1	-16.6	-16.1	-16.1	-18.1
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	30.9	30.9	30.4	30.9	30.9	28.9

	ch0	**ch0**	**ch0**	**ch0**	**ch0**	**ch0**
	2402	2402	2402	2402	2402	2402
	High	**High**	**High**	**High**	**High**	**High**
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	-16.6	-16.6	-17.1	-17.1	-16.9	-17.1
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	30.4	30.4	29.9	29.9	30.1	29.9

	ch39	**ch39**	**ch39**	**ch39**	**ch39**	**ch39**
	2480	2480	2480	2480	2480	2480
	High	**High**	**High**	**High**	**High**	**High**
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	-17.6	-17.6	-17.6	-17.6	-17.6	-17.6
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	29.4	29.4	29.4	29.4	29.4	29.4

Figure 80. Receiver blocking (out of band) rejection - Bluetooth LE - 1 Msps

Conclusion:

- Good margin, in line with the expected results

3.2.5.2.2 Receiver category 2, Bluetooth LE - 1 Msps

The test is performed with only one interfering signal at a time, for more details refer to the 300.328 2.1.1 chapter 4.3.1.12.4.3.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE - 1 Msps): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The desired signal is set to Pmin +6 dB (-82 dBm); the interferer is increased until the PER threshold is reached
- Channels under test: 0 and 39

Result:

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	High	Low	High
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-16.1	-18.1	-17.1	-19.1
300 328 limit (dBm)	-57	-57	-57	-57
Margin (dB)	40.9	38.9	39.9	37.9

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	High	Low	High
	2300	2583.5	2300	2583.5
Interferer level (dBm)	-16.1	-17.1	-16.1	-17.6
300 328 limit (dBm)	-47	-47	-47	-47
Margin (dB)	30.9	29.9	30.9	29.4

Figure 81. Receiver blocking (out of band) rejection Bluetooth LE - 1 Msps

Conclusion:

- Good margin, in line with the expected results

3.2.5.2.3 Receiver category 1, Bluetooth LE - 2 Msps

The test is performed with only one interfering signal at a time, for more details refer to the 300.328 2.1.1 chapter 4.3.1.12.4.2.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE - 2 Msps): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The desired signal is set to Pmin +6 dB (-82 dBm); the interferer is increased until the PER threshold is reached
- Channels under test: 0 and 39

Result:

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	High	Low	High
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-16.1	-14.6	-15.6	-16.6
300 328 limit (dBm)	-53	-53	-53	-53
Margin (dB)	36.9	38.4	37.4	36.4

	ch0	ch0	ch0	ch39	ch39	ch39
	2402	2402	2402	2480	2480	2480
	Low	Low	Low	Low	Low	Low
	2300	2330	2360	2300	2330	2360
Interferer level (dBm)	-14.1	-13.6	-15.6	-14.1	-14.6	-15.6
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	32.9	33.4	31.4	32.9	32.4	31.4

	ch0	ch0	ch0	ch0	ch0	ch0
	2402	2402	2402	2402	2402	2402
	High	High	High	High	High	High
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	-15.6	-13.6	-21.1	-13.6	-13.6	-13.6
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	31.4	33.4	25.9	33.4	33.4	33.4

	ch39	ch39	ch39	ch39	ch39	ch39
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	-15.6	-14.6	-15.6	-14.6	-14.6	-14.6
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	31.4	32.4	31.4	32.4	32.4	32.4

Figure 82. Receiver blocking (out of band) rejection Bluetooth LE - 2 Msps

Conclusion:

- Good margin, in line with the expected results

3.2.5.2.4 Receiver category 2, Bluetooth LE - 2 Msps

The test is performed with only one interfering signal at a time, for more details refer to the 300.328 2.1.1 chapter 4.3.1.12.4.3.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE - 2 Msps): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The desired signal is set to Pmin +6 dB (-82 dBm); the interferer is increased until the PER threshold is reached
- Channels under test: 0 and 39

Result:

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	High	Low	High
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-16.1	-14.6	-15.6	-16.6
300 328 limit (dBm)	-57	-57	-57	-57
Margin (dB)	40.9	42.4	41.4	40.4

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	High	Low	High
	2300	2583.5	2300	2583.5
Interferer level (dBm)	-14.1	-15.6	-14.1	-15.6
300 328 limit (dBm)	-47	-47	-47	-47
Margin (dB)	32.9	31.4	32.9	31.4

Figure 83. Receiver blocking (out of band) rejection Bluetooth LE - 2 Msps

Conclusion:

- Good margin, in line with the expected results

3.2.5.2.5 Receiver category 1, Bluetooth LE - 500 ksps (LR S=2)

The test is performed with only one interfering signal at a time, for details refer to the 300.328 2.1.1 chapter 4.3.1.12.4.2.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE - 500 ksps [LR S=2]): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The desired signal is set to Pmin +6 dB (-82 dBm); the interferer is increased until the PER threshold is reached
- Channels under test: 0 and 39

Result:

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	High	Low	High
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-20.6	-19.6	-20.1	-21.6
300 328 limit (dBm)	-53	-53	-53	-53
Margin (dB)	32.4	33.4	32.9	31.4

	ch0	ch0	ch0	ch39	ch39	ch39
	2402	2402	2402	2480	2480	2480
	Low	Low	Low	Low	Low	Low
	2300	2330	2360	2300	2330	2360
Interferer level (dBm)	-18.1	-19.1	-20.1	-19.6	-19.1	-22.1
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	28.9	27.9	26.9	27.4	27.9	25.9

	ch0	ch0	ch0	ch0	ch0	ch0
	2402	2402	2402	2402	2402	2402
	High	High	High	High	High	High
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	-19.1	-20.1	-19.6	-21.1	-19.1	-19.1
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	27.9	26.9	27.4	25.9	27.9	27.9

	ch39	ch39	ch39	ch39	ch39	ch39
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	-20.6	-19.6	-21.1	-21.1	-21.1	-21.1
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	26.4	27.4	25.9	25.9	25.9	25.9

Figure 84. Receiver blocking (out of band) rejection - Bluetooth LE - 500 ksps (LR S=2)

Conclusion:

- Good margin, in line with the expected results

3.2.5.2.6 Receiver category 2, Bluetooth LE - 500 ksps (LR S=2)

The test is performed with only one interfering signal at a time, for details refer to the 300.328 2.1.1 chapter 4.3.1.12.4.3.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE - 500 ksps [LR S=2]): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The desired signal is set to Pmin + 6 dB (-82 dBm); the interferer is increased until the PER threshold is reached
- Channels under test: 0 and 39

Result:

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	Low	High	High
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-21.1	-19.6	-21.1	-21.6
300 328 limit (dBm)	-57	-57	-57	-57
Margin (dB)	35.9	37.4	35.9	35.4

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	Low	High	High
	2300	2583.5	2300	2583.5
Interferer level (dBm)	-18.6	-19.1	-21.1	-21.1
300 328 limit (dBm)	-47	-47	-47	-47
Margin (dB)	28.4	27.9	25.9	25.9

Figure 85. Receiver blocking (out of band) rejection Bluetooth LE - 500 ksps (LR S=2)

Conclusion:

- Good margin, in line with the expected results

3.2.5.2.7 Receiver category 1, Bluetooth LE - 125 ksps (LR S=8)

The test is performed with only one interfering signal at a time, for details refer to the 300.328 2.1.1 chapter 4.3.1.12.4.2.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE - 125 ksps [LR S=8]): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The desired signal is set to Pmin +6 dB (-82 dBm); the interferer is increased until the PER threshold is reached
- Channels under test: 0 and 39

Result:

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	High	Low	High
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-31.1	-31.1	-31.1	-31.1
300 328 limit (dBm)	-53	-53	-53	-53
Margin (dB)	21.9	21.9	21.9	21.9

	ch0	ch0	ch0	ch39	ch39	ch39
	2402	2402	2402	2480	2480	2480
	Low	Low	Low	Low	Low	Low
	2300	2330	2360	2300	2330	2360
Interferer level (dBm)	-30.1	-31.1	-31.1	-31.1	-31.1	-31.1
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	16.9	15.9	15.9	15.9	15.9	15.9

	ch0	ch0	ch0	ch0	ch0	ch0
	2402	2402	2402	2402	2402	2402
	High	High	High	High	High	High
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	-31.1	-28.6	-30.6	-31.1	-30.6	-30.6
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	15.9	18.4	16.4	15.9	16.4	16.4

	ch39	ch39	ch39	ch39	ch39	ch39
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	-31.1	-31.1	-31.1	-31.1	-31.1	-31.1
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	15.9	15.9	15.9	15.9	15.9	15.9

Figure 86. Receiver blocking (out of band) rejection - Bluetooth LE - 125 ksps (LR S=8)

Conclusion:

- Good margin, in line with the expected results

3.2.5.2.8 Receiver category 2, Bluetooth LE - 125 ksps (LR S=8)

The test is performed with only one interfering signal at a time, for details refer to the 300.328 2.1.1 chapter 4.3.1.12.4.3.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE - 125 ksps [LR S=8]): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The desired signal is set to Pmin + 6 dB (-82 dBm); the interferer is increased until the PER threshold is reached
- Channels under test: 0 and 39

Result:

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	Low	High	High
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-21.1	-19.1	-31.1	-31.1
802.15.4 limit (dBm)	-57	-57	-57	-57
Margin (dB)	35.9	37.9	25.9	25.9

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	Low	High	High
	2300	2583.5	2300	2583.5
Interferer level (dBm)	-19.6	-19.1	-31.1	-31.1
802.15.4 limit (dBm)	-47	-47	-47	-47
Margin (dB)	27.4	27.9	15.9	15.9

Figure 87. Receiver Blocking (out of band) rejection Bluetooth LE - 125 ksps (LR S=8)

Conclusion:

- Good margin, in line with the expected results

3.2.5.3 Blocking interferers

3.2.5.3.1 Bluetooth LE 1 Msps

A CW is used as the interferer source to verify that the receiver performs satisfactorily with frequency outside the 2400 MHz - 2483.5 MHz.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE 1 Msps): Agilent N5182A
- Generator for the blocker: R&S SFU
- Criterion: PER < 30.8 % with 1500 packets
- Desired signal is set to -67 dBm; the interferer level is increased until the PER threshold is reached
- Channel under test: 12 (2426 MHz)

Table 17. Blocking interferers 1 Msps

Desired signal 2426 MHz @-67 dBm	Ch12	Ch12	Ch12	Ch12	-
	2426 MHz	2426 MHz	2426 MHz	2426 MHz	-
Interferer (MHz)	30 - 2000 (step 10 MHz)	2003 – 2399 (step 3 MHz)	2484 – 2997 (step 3 MHz)	3 GHz - 12.75 GHz (step 25 MHz)	-
Unwanted level (dBm)	-30	-35	-35	-30	-
Status (unwanted level)	PASS	PASS	PASS	PASS	-
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 10

Table 17. Blocking interferers 1 Msps*...continued*

Desired signal 2426 MHz @-67 dBm	**Ch12**	**Ch12**	**Ch12**	**Ch12**	**-**
	2426 MHz	**2426 MHz**	**2426 MHz**	**2426 MHz**	**-**
Interferer (MHz)	**30 - 2000 (step 10 MHz)**	**2003 – 2399 (step 3 MHz)**	**2484 – 2997 (step 3 MHz)**	**3 GHz - 12.75 GHz (step 25 MHz)**	**-**
Unwanted level (dBm)	**-30**	**-35**	**-35**	**-30**	**-**
Status (UnW level -50 dBm)	PASS	PASS	PASS	PASS	-
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 3

Conclusion:

- Good margin, in line with the expected results

3.2.5.3.2 Bluetooth LE 2 Msps

A CW is used as the interferer source to verify that the receiver performs satisfactorily with frequency outside the 2400 MHz -2483.5 MHz.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE 2 Msps): Agilent N5182A
- Generator for the blocker: R&S SFU
- Criterion: PER < 30.8 % with 1500 packets
- Desired signal is set to - 67 dBm; the interferer level is increased until the PER threshold is reached
- Channel under test: 12 (2426 MHz)

Table 18. Blocking Interferers - 2 Msps

Desired signal 2426 MHz @-67 dBm	**Ch 12**	**Ch 12**	**Ch 12**	**Ch 12**	**-**
	2426 MHz	**2426 MHz**	**2426 MHz**	**2426 MHz**	**-**
Interferer (MHz)	**30 - 2000 (step 10 MHz)**	**2003 – 2399 (step 3 MHz)**	**2484 – 2997 (step 3 MHz)**	**3 GHz - 12.75 GHz (step 25 MHz)**	**-**
Unwanted level (dBm)	**-30**	**-35**	**-35**	**-30**	**-**
Status (unwanted level)	PASS	PASS	PASS	PASS	-
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 10
Status (UnW level -50 dBm)	PASS	PASS	PASS	PASS	-
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 3

Conclusion:

- Good margin, in line with the expected results

3.2.5.3.3 Bluetooth LE 500 ksps (LR S=2)

A CW is used as the interferer source to verify that the receiver performs satisfactorily with frequency outside the 2400 MHz - 2483.5 MHz.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE-500 ksps [LR S=2]): Agilent N5182A
- Generator for the blocker: R&S SFU
- Criterion: PER < 30.8 % with 1500 packets
- Desired signal is set to -67 dBm; the interferer level is increased until the PER threshold is reached
- Channel under test: 12 (2426 MHz)

Table 19. Blocking interferers - 500 ksps

Desired signal 2426 MHz @-67 dBm	Ch12	Ch12	Ch12	Ch12	-
	2426 MHz	2426 MHz	2426 MHz	2426 MHz	-
Interferer (MHz)	30-2000 (step 10 MHz)	2003 – 2399 (step 3 MHz)	2484 – 2997 (step 3 MHz)	3 GHz-12.75 GHz (step 25 MHz)	-
Unwanted level (dBm)	-30	-35	-35	-30	-
Status (unwanted level)	PASS	PASS	PASS	PASS	-
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 10
Status (UnW level -50 dBm)	PASS	PASS	PASS	PASS	-
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 3

Conclusion:

- Good margin, in line with the expected results

3.2.5.3.4 Bluetooth LE 125 ksps (LR S=8)

A CW is used as the interferer source to verify that the receiver performs satisfactorily with frequency outside the 2400 MHz - 2483.5 MHz.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE-125 ksps [LR S=8]): Agilent N5182A
- Generator for the blocker: R&S SFU
- Criterion: PER < 30.8 % with 1500 packets
- Desired signal is set to -67 dBm; the interferer level is increased until the PER threshold is reached
- Channel under test: 12 (2426 MHz)

Table 20. Blocking interferers - 125 ksps

Desired signal 2426 MHz @-67 dBm	Ch12	Ch12	Ch12	Ch12	-
	2426 MHz	2426 MHz	2426 MHz	2426 MHz	-
Interferer (MHz)	30 - 2000 (step 10 MHz)	2003 – 2399 (step 3 MHz)	2484 – 2997 (step 3 MHz)	3 GHz-12.75 GHz (step 25 MHz)	-
Unwanted level (dBm)	-30	-35	-35	-30	-
Status (unwanted level)	PASS	PASS	PASS	PASS	-
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 10
Status (UnW level -50 dBm)	PASS	PASS	PASS	PASS	-
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 3

Conclusion:

- Good margin, in line with the expected results

3.2.6 Intermodulation

This test verifies that the receiver intermodulation performance is satisfactory.

Two interferers are used in combination with the wanted signal. One interferer is a sinusoid non-modulated signal and the second interferer is a modulated signal with PRSB15 data.

3.2.6.1 Bluetooth LE - 1 Msps

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE - 1 Msps): Agilent N5182A
- Generator for the first interferer (CW): R&S SML03
- Generator for the second interferer (PRBS15): R&S SFU
- Criterion: PER < 30.8 % with 1500 packets
- Desired signal is set to -67 dBm; the interferer levels are set to the data sheet specification values
- Channels under test: 0, 19, and 39

Results:

	ch0	ch0	ch0	ch0	ch0	ch0
	2402	2402	2402	2402	2402	2402
	Low	Low	Low	Low	Low	Low
Interferer1 (CW) (MHz)	-5	-4	-3	3	4	5
Interferer2 (Mod) (MHz)	-10	-8	-6	6	8	10
Interferer level (dBm)	**-21.6**	**-21.6**	**-22.6**	**-22.6**	**-22.6**	**-23.1**
Datasheet limit (dBm)	-24	-23	-23	-23	-23	-24
Margin (dB)	14.5	13.5	12.5	12.5	12.5	13.0

	ch19	ch19	ch19	ch19	ch19	ch19
	2440	2440	2440	2440	2440	2440
	Mid	Mid	Mid	Mid	Mid	Mid
Interferer1 (CW) (MHz)	-5	-4	-3	3	4	5
Interferer2 (Mod) (MHz)	-10	-8	-6	6	8	10
Interferer level (dBm)	**-22.6**	**-22.6**	**-22.6**	**-22.6**	**-22.6**	**-23.1**
Datasheet limit (dBm)	-24	-23	-23	-23	-23	-24
Margin (dB)	13.5	12.5	12.5	12.5	12.5	13.0

	ch39	ch39	ch39	ch39	ch39	ch39
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
Interferer1 (CW) (MHz)	-5	-4	-3	3	4	5
Interferer2 (Mod) (MHz)	-10	-8	-6	6	8	10
Interferer level (dBm)	**-23.1**	**-22.6**	**-23.1**	**-23.6**	**-23.1**	**-23.6**
Datasheet limit (dBm)	-24	-23	-23	-23	-23	-24
Margin (dB)	13.0	12.5	12.0	11.5	12.0	12.5

Figure 88. Intermodulation - 1 Msps

Conclusion:

- Good margin, in line with the expected results

3.2.6.2 Bluetooth LE - 2 Msps

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (Bluetooth LE - 2 Msps): Agilent N5182A
- Generator for the first interferer (CW): R&S SML03
- Generator for the second interferer (PRBS15): R&S SFU
- Criterion: PER < 30.8 % with 1500 packets
- Desired signal is set to -64 dBm; the interferer levels are set to the data sheet specification values
- Channels under test: 0, 19, and 39

Results:

	ch0	ch0	ch0	ch0	ch0	ch0
	2402	2402	2402	2402	2402	2402
	Low	Low	Low	Low	Low	Low
Interferer1 (CW) (MHz)	-10	-8	-6	6	8	10
Interferer2 (Mod) (MHz)	-20	-16	-12	6	8	10
Interferer level (dBm)	**-20.6**	**-20.6**	**-21.6**	**-21.6**	**-23.6**	**-24.1**
Datasheet limit (dBm)	-24	-23	-23	-23	-23	-24
Margin (dB)	15.5	14.5	13.5	13.5	11.5	12.0

	ch19	ch19	ch19	ch19	ch19	ch19
	2440	2440	2440	2440	2440	2440
	Mid	Mid	Mid	Mid	Mid	Mid
Interferer1 (CW) (MHz)	-10	-8	-6	6	8	10
Interferer2 (Mod) (MHz)	-20	-16	-12	6	8	10
Interferer level (dBm)	**-23.6**	**-23.6**	**-23.6**	**-23.6**	**-23.6**	**-24.1**
Datasheet limit (dBm)	-24	-23	-23	-23	-23	-24
Margin (dB)	12.5	11.5	11.5	11.5	11.5	12.0

	ch39	ch39	ch39	ch39	ch39	ch39
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
Interferer1 (CW) (MHz)	-10	-8	-6	6	8	10
Interferer2 (Mod) (MHz)	-20	-16	-12	6	8	10
Interferer level (dBm)	**-24.1**	**-23.6**	**-24.1**	**-24.6**	**-24.1**	**-24.6**
Datasheet limit (dBm)	-24	-23	-23	-23	-23	-24
Margin (dB)	12.0	11.5	11.0	10.5	11.0	11.5

Figure 89. Intermodulation - 2 Msps

Conclusion:

- Good margin, in line with the expected results

3.3 Return loss

This section lists the details about return losses.

3.3.1 RF path with matching components using VDD_PA_2G4 pin

Measurements are done using the SMA connector where:

- C4 capacitor is mounted
- C3 capacitor is not mounted

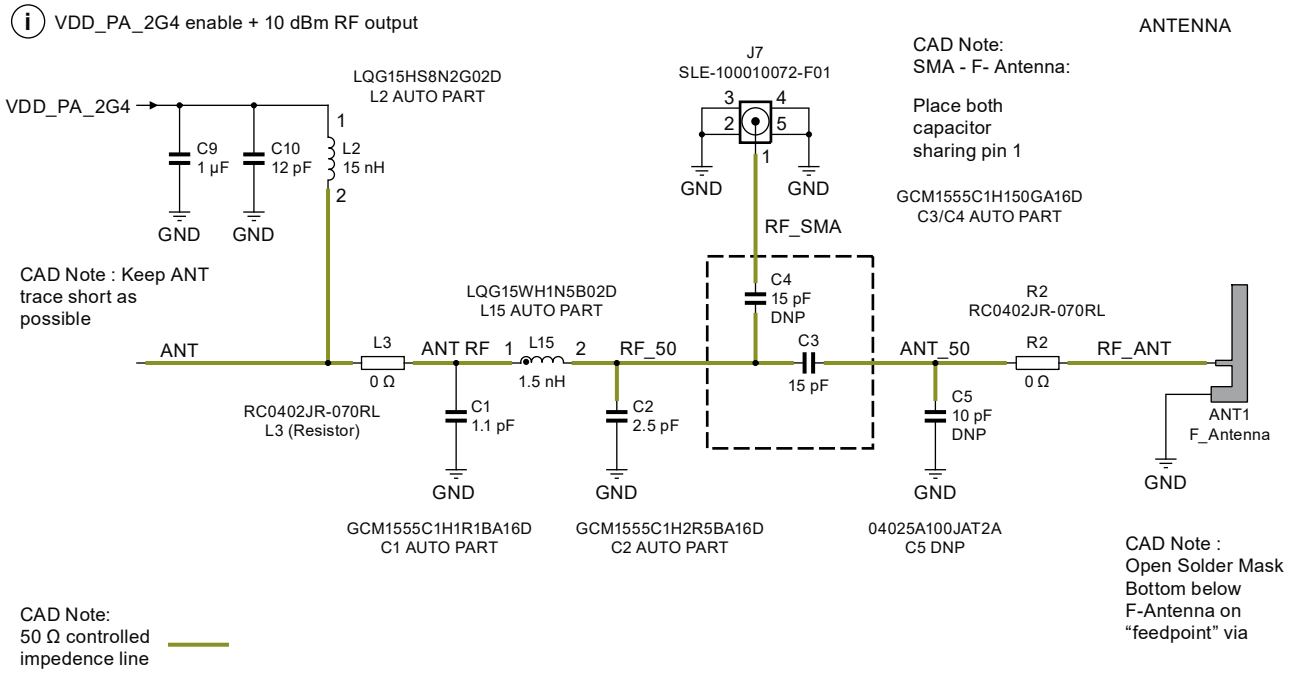


Figure 90. RF matching

Matching components are shown in Table 21 and Table 22:

Table 21. Inductors

Reference	Value	Description	Mfr. name	Mfr. part number
L2	15 nH	IND -- 0.015 mH @ 100 MHz 450 mA +/-5% 0402	Murata	LQG15HZ15NJ02D
L3	0 Ω	Shunt	-	-
L15	1.5 nH	IND -- 0.0015 mH @ 100 MHz 1000 mA +/-0.1 nH 0402	Murata	LQG15WH1N5B02

Table 22. Capacitors

Reference	Value	Description	Mfr. name	Mfr. part number
C2	2.5 pF	CAP CER 2.5 pF 50 V 0.1 pF C0G 0402	Murata	GCM1555C1H2R5BA16
C1	1.1 pF	CAP CER 1.1 pF 50 V 0.1 pF C0G 0402	Murata	GCM1555C1H1R1BA16
C10	12 pF	CAP CER 12 pF 50 V 5 % C0G AEC-Q200 0402	Murata	GCM1555C1H120JA16D
C9	1 µF	CAP CER 1 µF 10 V 10 % X7S AEC-Q200 0402	Murata	GCM155C71A105KE38D

3.3.2 RX

In the RX mode, the return loss measurement is performed by setting the LNA gain of KW45 to the maximum.

Hardware: X-KW45B41Z-EVK

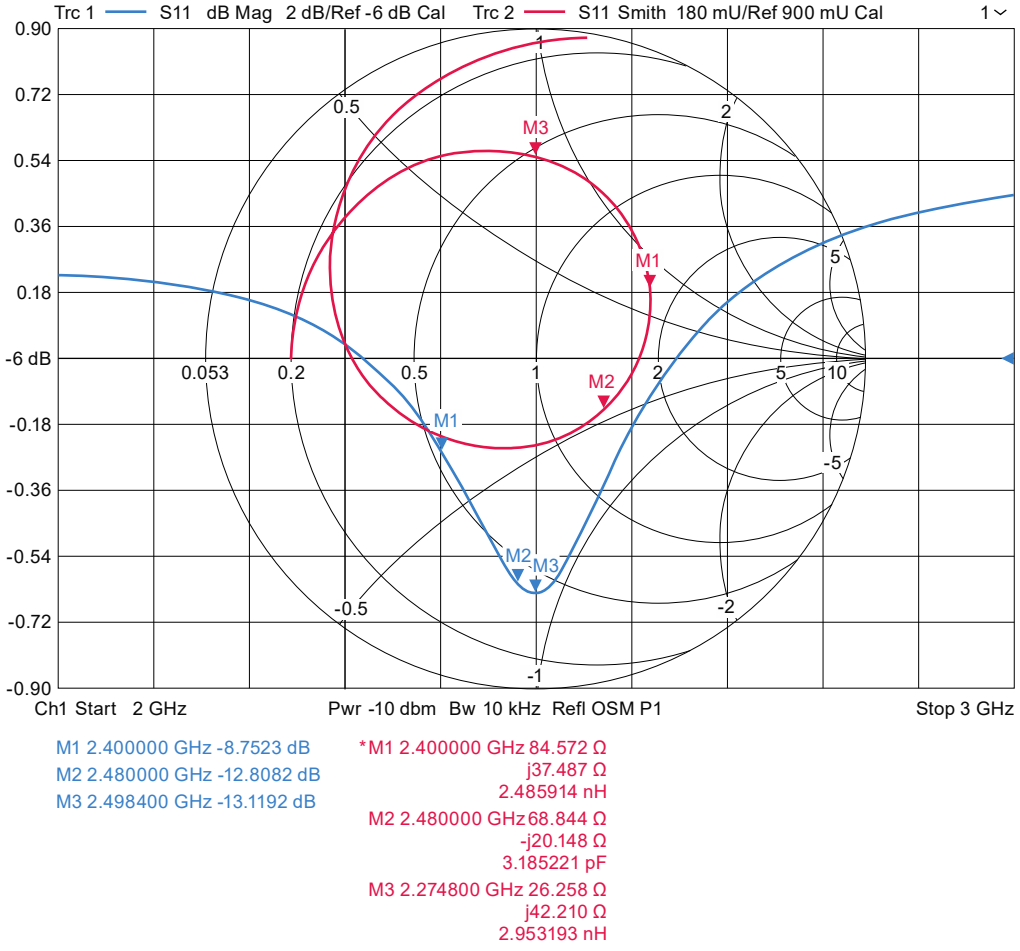


Figure 91. S11 diagram (RX mode)

Results:

- Return loss: -12.8 dB (2.48 GHz) < S11 < -8.7 dB (2.4 GHz)

Note: *There is no specification for the return loss.*

Conclusion:

- The return loss (S11) is lower than -8 dB

3.3.3 TX

In the TX mode, the return loss measurement is performed by setting the KW45 RF output power to the minimum.

Hardware: KW45B41Z-EVK

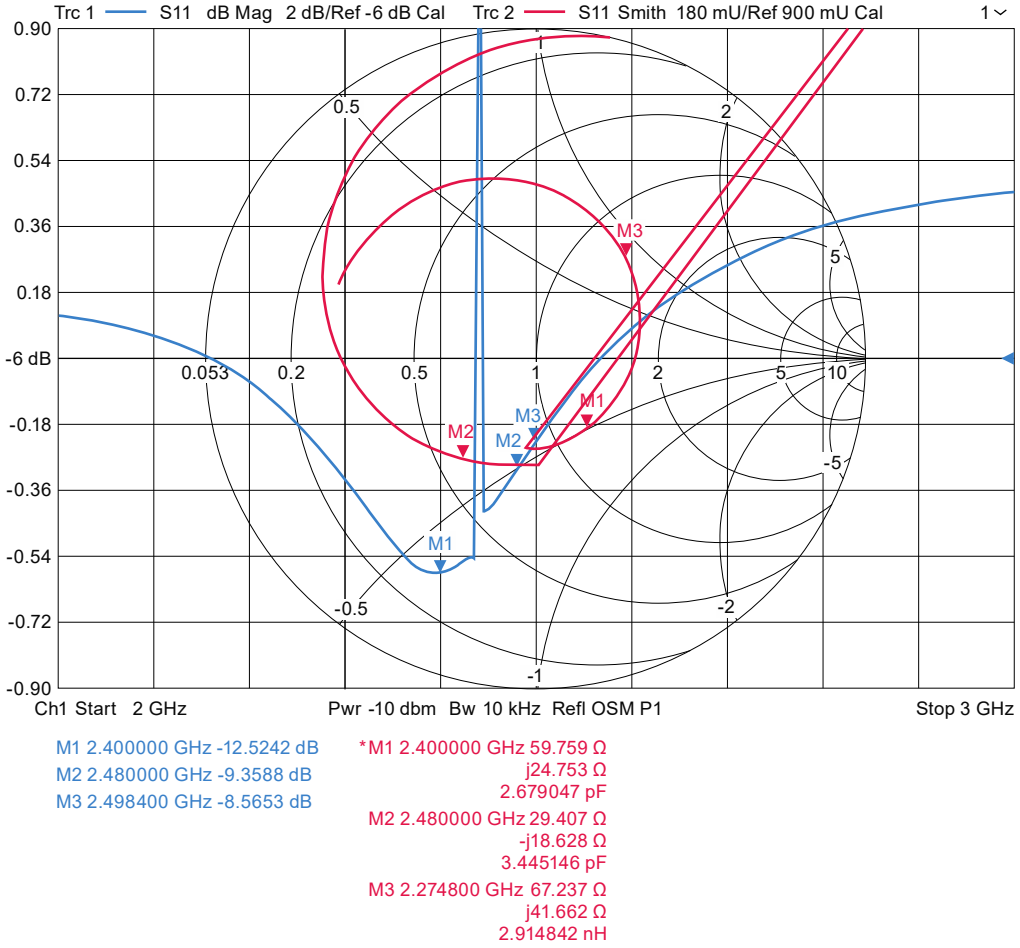


Figure 92. S11 diagram (TX mode)

Results: Return loss: -12.5 dBm (2.4 GHz) < S11 < -9.3 dB (2.48 GHz)

Note: *There is no specification for the return loss.*

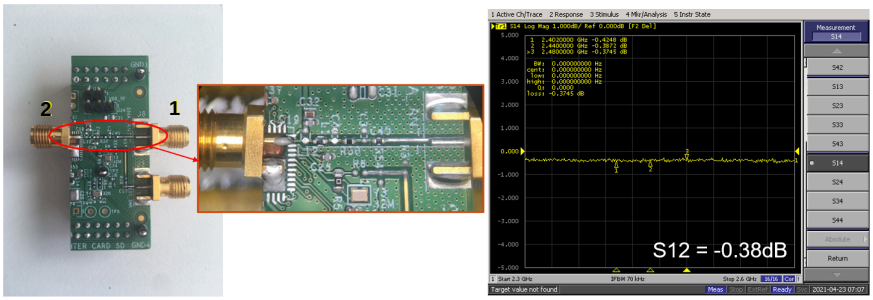
Conclusion:

- The return loss (S11) is lower than -9 dB

3.3.4 RF line insertion loss

To extract RF line insertion loss, the steps are as follows:

1. Cut the board
2. To isolate the RF line, solder SMA on pin ANT_2P4GHZ
3. Replace default resistor by 0 Ω resistor



This measure represents not only RF line insertion losses but also the following::
Global losses = Insertion losses + Mismatch losses

Figure 93. Isolate RF line

$$\text{Insertion losses} = \frac{1}{1-|S11|^2} \times |S11|^2$$

With this equation, we can quantify insertion losses and mismatch losses.

$$\text{Mismatch losses} = -10 \log 1 - \Gamma^2$$

$\Gamma = 10^{-15.3/20} = 0.171791$

Mismatch losses = -10 log (1- 0.171791^2) = -0.13 dB

Insertion losses = Global losses - Mismatch losses

Insertion losses = -0.38 - (-0.13)

Insertion losses = -0.25 dB

In additional to insertion line losses, we should add SMD insertion losses estimate at 0.1 dB.

4 Conclusion

Beyond the RED and Bluetooth LE 5.0 compliance, these radio tests prove a good performance of the KW45B41Z wireless MCU.

5 Perform pre-certification tests

The first two hardware connectors must flash the application described in the Section 1.2 (Connectivity test and HCI_bb application examples):

- The SWD connector is mandatory to flash the KW45 application example:
  - HCI commands (DTM) via UART to USB cable (for example, CMW)
  - Tera Term terminal emulator, which is used to communicate with the KW45 MCU via UART to USB cable (PC)

SWD connector J16 description (from EVK-KW45):

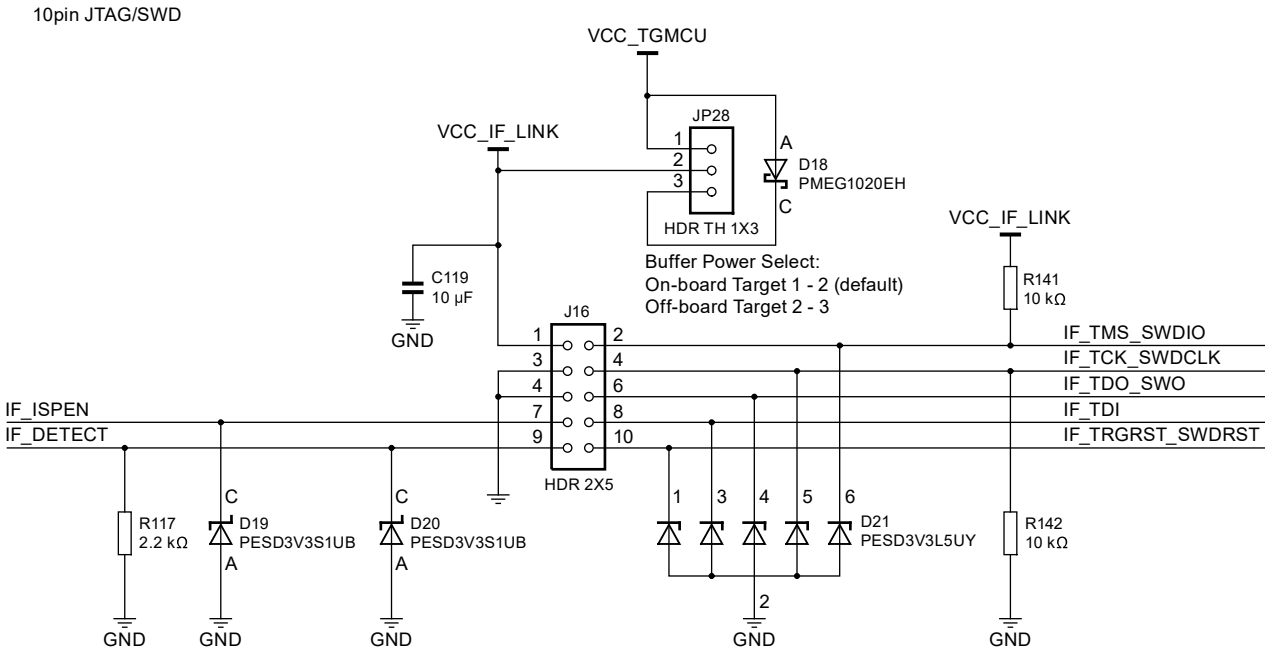


Figure 94. J16 SWD connector

UART connector:

PTA16 (UART0_RX) and PTA17 (UART0_TX) or PTC2 (UART1_RX) and PTC3 (UART1_TX) must be accessible to connect a UART to USB cable to a PC. UART1 is the default UART on the EVK KW45 board.

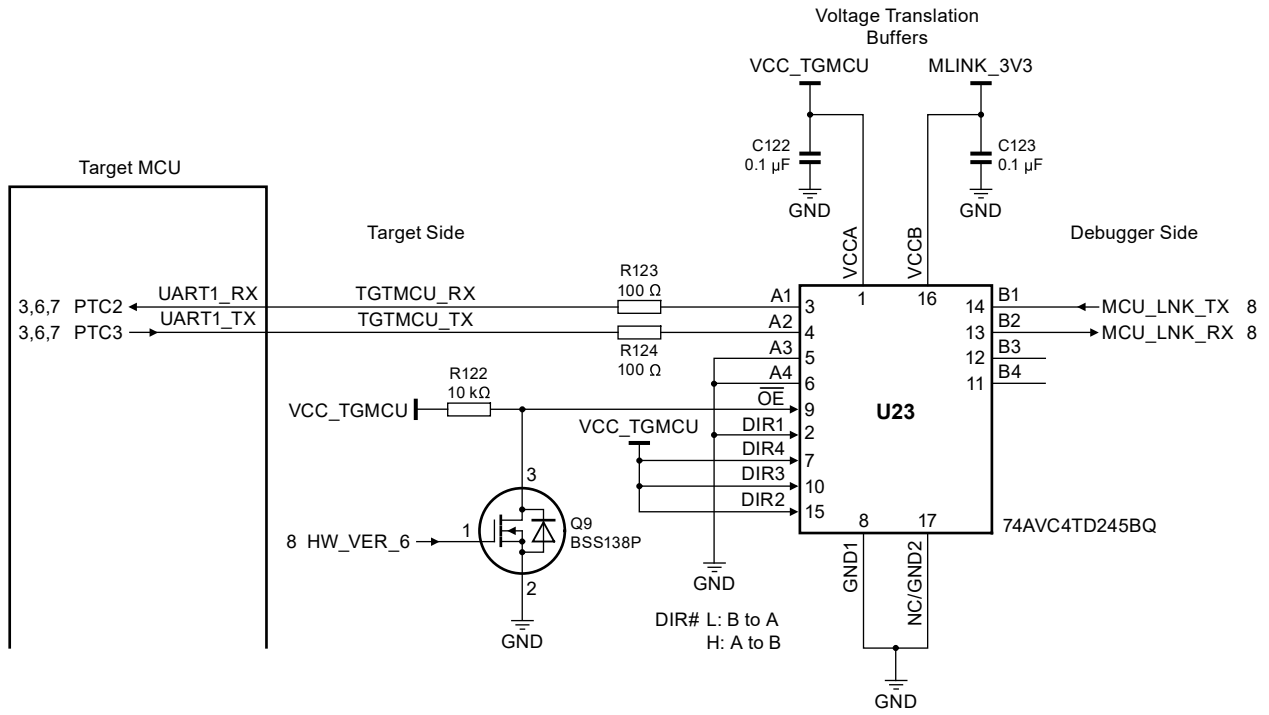


Figure 95. UART1 connection between the KW45 and the MLINK debugger (EVK board)

For more details, see the KW45B41Z webpage.

The hardware user guide and hardware user manual can help you define your PCB.

6 References

The references used to supplement this application note are as follows:

- **ETS EN 300 328 2.2.1 (04-2019)**: European telecommunication standard - Radio Equipment and Systems (RES) Wideband data transmission systems; Technical characteristics, and test conditions for data transmission equipment operating in the 2.4 GHz ISM band and using spread spectrum modulation techniques.
- **RF-PHY TS 5.0.2 (12-2017):** Bluetooth Test Specification. This document defines test structures and procedures for qualification testing of Bluetooth implementations of the Bluetooth Low Energy RF PHY.
- **FCC Part 15:** Operation to FCC Part 15 is subject to two conditions. First, the device may not cause harmful interference and, second, the device must accept any interference received, including interference that may cause undesired operation. Therefore, there is no guaranteed quality of service when operating a Part 15 device.

7 Revision history

Table 23 summarizes the changes done to this document since the initial release.

Table 23. Revision history

Revision history	Date	Substantive changes
1	28 April 2023	• Added keywords • Updated the web link for KW45B41Z Data Sheet in Section 1 • Updated the web link for Getting Started KW45 in Section 1.2 • Multiple editorial changes throughout the entire document • Figures updated throughout the entire document • The grammar and sentence structure of the entire document has been enhanced
0	06 January 2023	Initial release

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